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Original Article / *Özgün Makale*

Factors associated with increased intra-abdominal pressure in patients undergoing cardiac surgery

Kalp cerrahisi geçiren hastalarda intraabdominal basınç artışı ile ilişkili faktörler

Bahriye Kılıç[1], Nihan Yapıcı[2], Fikri Yapıcı[3], Ali Sait Kavaklı[4], Türkan Kudsioğlu[2], Abdullah Kılıç[1], Zuhal Aykaç[5]

Institution where the research was done:
University of Health Sciences Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital, Istanbul, Turkey

Author Affiliations:
[1]Department of Anesthesiology and Reanimation, Medicine Hospital, Istanbul, Turkey
[2]Department of Anesthesiology and Reanimation, University of Health Sciences Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital, Istanbul, Turkey
[3]Department of Cardiovascular Surgery, Memorial Ataşehir Hospital, Istanbul, Turkey
[4]Department of Anesthesiology and Reanimation, University of Health Sciences Antalya Training and Research Hospital, Antalya, Turkey
[5]Department of Anesthesiology and Reanimation, Marmara University School of Medicine, Pendik Training and Research Hospital, Istanbul, Turkey

ABSTRACT

Background: The aim of this study was to investigate the intra-abdominal pressure changes and risk factors associated with increased intra-abdominal pressure in patients undergoing cardiac surgery.

Methods: Between July 2016 and January 2017, a total of 100 patients (74 males, 26 females; mean age 55.9±14.3 years; range, 19 to 75 years) who underwent cardiac surgery under cardiopulmonary bypass were included in the study. Patients' data including demographic and clinical characteristics and intra- and postoperative data were recorded. Intra-abdominal pressure was measured via a urinary catheter after anesthesia induction, on admission to the intensive care unit, and at postoperative 12 and 24 h. The patients were divided into two groups according to the intra-abdominal pressure as Group 1 (≥12 mmHg; n=49) and Group 2 (<12 mmHg; n=51).

Results: In the univariate regression analysis, high intra-abdominal pressure was related to intra-abdominal pressure measured after anesthesia induction (Odds Ratio =0.70, p=0.001), age (odds ratio=0.95, p=0.004), hypertension (odds ratio=4.51, p=0.0001), duration of cardiopulmonary bypass (odds ratio=0.97, p=0.0001), intraoperative lactate levels (odds ratio=0.53, p=0.0001), use of red blood cells (odds ratio=0.24, p=0.0001), use of dopamine (odds ratio=0.21, p=0.002), dobutamine (odds ratio=0.28, p=0.005), use of noradrenaline (odds ratio=0.25, p=0.016), postoperative lactate levels (odds ratio=0.60, p=0.0001), duration of cross-clamp (odds ratio=0.97, p=0.0001), atrial fibrillation (odds ratio=5.89, p=0.004), and acute kidney injury (odds ratio=8.33, p=0.048). In the multivariate analysis, the intra-abdominal pressure at baseline (odds ratio=0.70, p=0.045), age (odds ratio=0.93, p=0.032), hypertension (odds ratio=6.87, p=0.023), duration of cardiopulmonary bypass (odds ratio=0.98, p=0.062), intraoperative lactate levels (odds ratio=0.57, p=0.035), and use of red blood cells (odds ratio=0.19, p=0.003) remained statistically significant.

Conclusion: Our study results suggest that age, hypertension, duration of cardiopulmonary bypass, intraoperative lactate levels, and use of red blood cells are risk factors associated with elevated intra-abdominal pressure in patients undergoing cardiac surgery. Increased awareness of these risk factors and the addition of intra-abdominal pressure measurement to the standard follow-up scheme in patients with variable hemodynamics, low cardiac output, and high lactate levels in the intensive care unit may be useful in early diagnosis of complications and in decreasing morbidity.

Keywords: Cardiac surgery, cardiopulmonary bypass. intra-abdominal pressure, risk factor.

ÖZ

Amaç: Bu çalışmada kalp cerrahisi yapılan hastalarda intraabdominal basınç değişiklikleri ve artmış intraabdominal basınç ile ilişkili risk faktörleri araştırıldı.

Çalışma planı: Temmuz 2016 - Ocak 2017 tarihleri arasında kardiyopulmoner baypas ile kalp cerrahisi yapılan toplam 100 hasta (74 erkek, 26 kadın; ort. yaş 55.9±14.3 yıl; dağılım, 19-75 yıl) çalışmaya alındı. Hastaların demografik ve klinik özellikleri ve ameliyat sırası ve ameliyat sonrası verileri kaydedildi. İntraabdominal basınç, anestezi indüksiyonu sonrası, yoğun bakım ünitesine girişte ve ameliyat sonrası 12. ve 24. saatlerde üriner kateter ile ölçüldü. Hastalar intrabdominal basınca göre Grup 1 (≥12 mmHg; n=49) ve Grup 2 (<12 mmHg; n=51) olmak üzere iki gruba ayrıldı.

Bulgular: Tek değişkenli regresyon analizinde yüksek intraabdominal basınç anestezi indüksiyonundan sonra ölçülen intraabdominal basınç (olasılık oranı=0.70, p=0.001), yaş (olasılık oranı=0.95, p=0.004), hipertansiyon (olasılık oranı=4.51, p=0.0001), kardiyopulmoner baypas süresi (olasılık oranı=0.97, p=0.0001), ameliyat sırası laktat düzeyleri (olasılık oranı=0.53, p=0.0001), eritrosit kullanımı (olasılık oranı=0.24, p=0.0001), dopamin kullanımı (olasılık oranı=0.21, p=0.002), dobutamin (olasılık oranı=0.28, p=0.005), noradrenalin kullanımı (olasılık oranı=0.25, p=0.016), ameliyat sonrası laktat düzeyleri (olasılık oranı=0.60, p=0.0001), kros-klemp süresi (olasılık oranı=0.97, p=0.000), atriyal fibrilasyon (olasılık oranı=5.89, p=0.004) ve akut böbrek hasarı (olasılık oranı=8.33, p=0.048) ile ilişkili bulundu. Çok değişkenli analizde ise, başlangıç intraabdominal basınç (olasılık oranı=0.70, p=0.045), yaş (olasılık oranı=0.93, p=0.032), hipertansiyon (olasılık oranı=6.87, p=0.023), kardiyopulmoner baypas süresi (olasılık oranı=0.98, p=0.062), ameliyat sırası laktat düzeyleri (olasılık oranı=0.57, p=0.035) ve eritrosit kullanımı (olasılık oranı=0.19, p=0.003) istatistiksel olarak anlamlı olmayı sürdürdü.

Sonuç: Çalışma sonuçlarımız kalp cerrahisi yapılan hastalarda yaş, hipertansiyon, kardiyopulmoner baypas süresi, ameliyat sırası laktat düzeyleri ve eritrosit kullanımının intraabdominal basınç yüksekliği ile ilişkili risk faktörleri olduğunu göstermektedir. Bu risk faktörlerinin bilinirliğinin artması ve intraabdominal basınç ölçümünün ameliyat sonrası değişken hemodinami, düşük kalp debisi ve yüksek laktat düzeyleri olan hastaların standart takip şemasına eklenmesi, komplikasyonların erken tanısı ve morbiditenin azaltılmasında yararlı olabilir.

Anahtar sözcükler: Kalp cerrahisi, kardiyopulmoner baypas, intraabdominal basınç, risk faktörü.

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Correspondence: Nihan Yapıcı, MD. SBÜ Dr. Siyami Ersek Göğüs Kalp ve Damar Cerrahisi Eğitim ve Araştırma Hastanesi Anesteziyoloji ve Reanimasyon Kliniği, 34668 Üsküdar, İstanbul, Türkiye. Tel: +90 532 - 356 55 58 e-mail: nihanyapici@gmail.com

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Intra-abdominal pressure (IAP) values greater than 12 mmHg may represent intra-abdominal hypertension (IAH), which may in turn reduce the microcirculatory blood flow in most organs of the abdominal cavity.[1] Increased IAP may develop after massive fluid resuscitation, multiple transfusions, hypothermia, severe coagulation disorders, and as a consequence of normovolemic hemodilution during cardiopulmonary bypass (CPB).[2] High levels of IAP (>20 mmHg) may cause elevation of diaphragm, resulting in decreased cardiac output which subsequently causes increased central venous pressure (CVP), pulmonary blood pressure, right atrial pressure, and pulmonary vascular resistance.[1,2] Rapid deterioration of these parameters may even yield a multiple organ failure in the immediate postoperative period.[3]

To the best of our knowledge, there are few studies about the changes in IAP during and after cardiac procedures.[2-6] Although it is a cause of serious organ failure and mortality, there is very limited information about its incidence and management even in general intensive care patients.[7] In the present study, we aimed to investigate IAP changes and factors related to increased IAP during and after cardiac surgery.

PATIENTS AND METHODS

This study was conducted at Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital between July 2016 and January 2017. A total of 100 patients (74 males, 26 females; mean age 55.9±14.3 years; range, 19 to 75 years) who underwent cardiac surgery under CPB were included in the study. Patients with a history of previous bladder or urinary tract surgery, chronic renal insufficiency, neurogenic bladder, cerebrovascular disease, peripheral arterial occlusive disease, and active urinary tract infection were excluded from the study. The patients who met the inclusion criteria were divided into two groups according to the IAP measurements: Group 1 (≥12 mmHg at any measurement; n=49) and Group 2 (<12 mmHg; n=51). A written informed consent was obtained from each patient. The study protocol was approved by the Ethics Committee of Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital (No. 28001928-051.99). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Management protocol

On arrival to the operating room, a 16G peripheral venous catheter was placed. Standard monitoring included invasive blood pressure (via 20G catheter in the radial artery), five-lead electrocardiography, pulse oximetry, end-tidal carbon dioxide, bispectral index (BIS), diuresis, and body core temperature. In all patients, general anesthesia was induced with a 0.05 to 0.1 mg/kg intravenous (IV) bolus of midazolam, propofol 1 to 2 mg/kg, fentanyl 5 to 10 μg/kg, and rocuronium 0.6 mg/kg. Anesthesia was maintained with 50% air and 0.8 to 1.5 age-adjusted minimum alveolar anesthetic concentration of desflurane calculated by the monitor software (Primus Drager, Luebeck, Germany) with positive pressure ventilation in a circle system. End-tidal carbon dioxide was maintained between 30 and 35 mmHg. The BIS value was kept between 40 and 60, and the maintenance dosage was adjusted, if necessary. Repeated injections of fentanyl and rocuronium were administered, when necessary. After induction of anesthesia, a central venous catheter was inserted in the right internal jugular vein. An esophageal temperature probe and a urine catheter were also placed.

Before CPB, 300 IU/kg heparin was administered to provide an activated clotting time (ACT) >400 sec. If the ACT was below 400 sec, additional doses of 5,000 IU were used. A non-pulsatile CPB with a flow of 2.2 to 2.4 L/min/m^2 was used to maintain a mean arterial blood pressure of >55 mmHg. A total of 1,000 to 1,500 mL of Ringer solution was used as a priming volume. The CPB temperature was maintained at 33 to 34°C. Intermittent antegrade cardioplegia was used for myocardial protection. Target hemoglobin levels were >7.5 g/dL. Heparin was antagonized with protamine sulfate at a ratio of 1:1 after CPB was terminated.

Postoperative care in the intensive care unit (ICU) was provided according to the institutional standard of care. After surgery, the patients were transferred to the ICU for full monitoring. In the ICU, the patients were mechanically ventilated with synchronized intermittent-mandatory ventilation (SIMV) plus pressure support (PS) mode or pressure-regulated volume control with a fraction of inspired oxygen (FiO_2) of 0.6, respiratory rate of 10 to 14, and a positive end-expiratory pressure (PEEP) of 5 to 8. Dopamine and/or dobutamine and/or norepinephrine were used to maintain systolic blood pressure above 90 mmHg, when necessary. The dose of inotropic support was determined according to the patient's body weight. Doses of dopamine or dobutamine were increased or decreased by 2 μg/kg/min and doses of norepinephrine by 0.02 μg/kg/min to maintain the mean arterial pressure above 65 mmHg. Extubation criteria as follows: being awake and cooperative, fully rewarmed, hemodynamically stable, and having blood gases within the normal ranges. When drainage via chest tubes was less than 10 mL/h for at least four h, chest tubes were removed.

The IAP measurement was performed after the induction of anesthesia, immediately after admission to the ICU, at 12 and 24 h postoperatively. The IAP was measured in the supine position at end-expiration via the bladder pressure through the instillation of 25 mL of sterile saline with a pressure transducer zeroed at the level of the mid-axillary line.[8] A three-way stopcock was connected to a pressure transducer. A high-pressure tubing was attached to a port on the urinary drainage tubing and to the stopcock. After zeroing, the urinary drainage tubing was clamped immediately distal the connection. Twenty-five mL of sterile saline were injected retrogradely into the bladder. After a period of 30 to 60 sec, the bladder pressure was recorded.

Data collection

Demographic data such as age, gender, body surface area, smoking status, co-existing morbidities including diabetes mellitus (DM), hypertension (HT), chronic obstructive pulmonary disease (COPD), and atrial fibrillation (AF), previous surgical interventions, preoperative ejection fraction, levels of hematocrit, glucose, creatinine, and lactate were recorded for each patient. The use of intra-aortic balloon pump, pacemaker, inotropic agent, blood products, and urine output, CVP and IAP, central venous O_2 saturation ($ScvO_2$), the length of ICU stay, extubation time, duration of hospitalization, and postoperative complications were also noted. Acute kidney injury (AKI) was defined according to the risk class definition of the Risk, Injury, Failure, Loss of kidney function, and End-stage kidney disease (RIFLE) criteria.[9]

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 21.0 statistical software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed in mean ± standard deviation (SD), while categorical variables were expressed in number and frequency. All numerical data were tested for normal distribution by the Kolmogorov-Smirnov test. Differences between the mean values for normally distributed variables were compared using the Student's t test. Non-normally distributed variables and ordinal variables were compared with the Mann-Whitney U test and Wilcoxon signed-rank test. The chi-squared test and Fisher's exact test were used to analyze categorical data, where appropriate. Comparative analysis of repeated-measurement variables was performed by repeated-measures analysis of variance (ANOVA) for inter-group comparison. For intra-group comparison, the repeated-measures ANOVA with adjustment for multiple comparisons to control the type 1 error with Bonferroni test was used for the changes in IAPs measured at immediately after anesthesia induction, immediately after admission to ICU, and at 12 and 24 h postoperatively. Pairwise comparisons between the groups were performed using the paired t-test. A logistic regression analysis was performed with the IAH as the dependent outcome variable. A univariate analysis was performed initially. Variables significantly associated with the IAP in the univariate analysis were included in a multivariate analysis. The Hosmer-Lemeshow test was used to assess goodness-of-fit. The odds ratio (OR) and 95% confidence interval (CI) were calculated for each variable. The Spearman's rank correlation test was used for inter-point and overall comparisons. A p value of <0.05 was considered statistically significant.

RESULTS

Of a total of 100 patients, 49 (49%) had an IAP of ≥12 mmHg, while 51 (51%) had an IAP lower than 12 mmHg at all time points. The mean age was significantly higher in Group 1 (58.7±13.5 vs. 51.7±13.4, respectively; p=0.010). Atrial fibrillation, hypertension, and aortic atheroma were significantly more common in Group 1 (p=0.002, p=0.016, and p=0.003, respectively). There were no significant differences in terms of gender, body surface area, smoking, diabetes mellitus, COPD, type of surgery, and preoperative creatinine and hematocrit levels between the groups. Demographic and clinical characteristics of the patient groups are presented in Table 1.

Duration of cross-clamp and duration of CPB were significantly longer in Group 1 (p=0.0001 and p=0.0001, respectively). Intraoperative blood glucose levels were significantly higher in Group 1 (p=0.042). Then mean ScvO2 value was 60.1±7.8 in Group 1 and 64.1±4.7 in Group 2 (p=0.002). The amount of intraoperative inotropic support was significantly higher in Group 1 than Group 2. Similarly, the amount of red blood cells was significantly higher in Group 1 (p=0.0001) (Table 2).

The mean postoperative lactate levels were significantly higher in Group 1 (p=0.001). The amount of postoperative inotropic support was significantly higher in Group 1 than Group 2. The amount of red blood cells and fresh frozen plasma in the postoperative period were higher in Group 1 (p=0.0001 and p=0.007, respectively). Duration of ICU stay was significantly longer in Group 1 (1.5±1.3 vs. 1.1±0.3

Table 1. Demographic and clinical characteristics of patients

	All patients (n=100)			Group 1 (n=49)			Group 2 (n=51)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			55.9±14.3			58.7±13.5			51.7±13.4	0.010*
Gender										0.137
Male	74	74		33	67.3		41	80.4		
Female	26	26		16	32.7		10	19.6		
Body surface area (m^2)			1.82±0.17			1.86±0.13			1.79±0.12	0.829
Smoking	47	47		27	55.1		20	39.2		0.112
Diabetes mellitus	36	36		17	34.7		19	37.3		0.790
Hypertension	51	51		31	63.3		20	39.2		0.016*
COPD	7	7		5	10.2		2	3.9		0.264
Aortic atheroma	11	11		10	-		1	-		0.003*
Atrial fibrillation	20	20		16	32.7		4	7.8		0.002*
Surgery										
CABG	59	59		25	51		34	66.7		0.088
Valve replacement	10	10		8	16.3		2	3.9		0.137
CABG plus valve replacement	31	31		16	32.7		15	29.4		0.849
Creatinine (mg/dL)			-			1.7±2.6			1.4±2.2	0.481
Hematocrit (%)			-			37.7±5.1			38.7±4.6	0.295
Duration of cross-clamp (min)			76±41			93±47			60±25	0.0001*
Duration of CPB (min)			109±47			130±53			88±27	0.0001*

SD: Standard deviation; COPD, chronic obstructive pulmonary disease; CABG: Coronary artery bypass grafting; CPB: Cardiopulmonary bypass; * p<0.05.

days, respectively; p=0.010) (Table 3). The incidence of AKI was 14.3% (n=7) in Group 1 and 2% (n=1) in Group 2 (p=0.029).

In Group 1, the mean IAP increased immediately after the admission to ICU (12.2±0.7 vs. 10.1±2.4, respectively; p=0.0001), at postoperative 12 h (13±3.8 vs. 10.1±2.4, respectively; p=0.0001) and at postoperative 24 h (14.7±3.2 vs. 10.1±2.4, respectively; p=0.0001), compared to baseline values. In Group 2, there were no significant differences in any time point compared to baseline values (Figure 1).

The univariate and multivariate analysis results are shown in Table 4. In the univariate analysis, the IAP (immediately after anesthesia induction), age, HT,

Table 2. Intraoperative data

	Group 1 (n=49)			Group 1 (n=49)			
	n	%	Mean±SD	n	%	Mean±SD	*p*
Glucose (mg/dL)			171.6±47.7			154.8±32.6	0.042*
Lactate (mmol/L)			3.2±2			2.7±1.2	0.057
Central venous oxygen saturation			62.3±8.2			65.4±5.3	0.026*
Dopamine consumption (µg/kg/min)			2.4±3			0.4±1.7	0.0001*
Dobutamine consumption (µg/kg/min)			2.4±3.1			0.6±1.7	0.0001*
Noradrenaline consumption (µg/kg/min)			1.1±0.6			0.4±0.2	0.0001*
Fluid balance (mL)			2,205±2,013			1,868±663	0.258
Intraoperative urine output (mL)			820±476			858±488	0.356
Red blood cell (unit)			1.35±1			0.5±0.7	0.0001*
Fresh frozen plasma			0.8±0.5			0.7±0.5	0.633
Need for intraaortic balloon pump	1	2		0	0		0.490
Need for ultrafiltration	5	10.2		0	0		0.025*
Need for pacemaker	3	6.1		1	2		0.357

SD: Standard deviation; * p<0.05.

Table 3. Postoperative data

	Group 1 (n=49)	Group 2 (n=51)	
	Mean±SD	Mean±SD	*p*
Glucose (mg/dL)	211.2±74.1	187.3±53.8	0.067
Lactate (mmol/L	5.2±3.4	3.4±1.6	0.001*
Central venous oxygen saturation	60.1±7.7	64.1±4.6	0.002*
Dopamine consumption (µg/kg/min)	2.7±3.9	0.3±1.5	0.002*
Dobutamine consumption (µg/kg/min)	2.2±4.1	0.2±1.2	0.002*
Noradrenaline consumption (µg/kg/min)	2.9±1.6	1.1±0.9	0.001*
Total fluid balance at postoperative 24 h (mL)	1,703±1,050	1,850±1,146	0.545
Total urine output at postoperative 24 h (mL)	1,983±713	2,520±682	0.070
Red blood cell (unit)	2.3±1	0.5±0.7	0.0001*
Fresh frozen plasma (unit	1.6±0.7	1.2±0.6	0.007*

SD: Standard deviation; * p<0.05.

duration of CBP, intraoperative lactate levels, use of red blood cell, use of dopamine, use of dobutamine, use of noradrenaline, postoperative lactate levels, duration of cross-clamp, AF and AKI were significantly found to be associated with IAP. In the multivariate analysis, the IAP (immediately after anesthesia induction) (p=0.045), age (p=0.032), HT (p=0.023), duration of CBP (p=0.062), intraoperative lactate levels (p=0.035), and use of red blood cell (p=0.003) remained significant compared to the other covariates. There were significant correlations between the IAP and CVP immediately after anesthesia induction (p=0.023, r=0.325), immediately after admission to ICU (p=0.001, r=0.465), at postoperative 12 h (p=0.001, r=0.457), and at postoperative 24 h (p=0.004, r=0.405). There was also a significant correlation between IAP and CVP in the overall analysis (p=0.0001, r=0.499) (Figure 2).

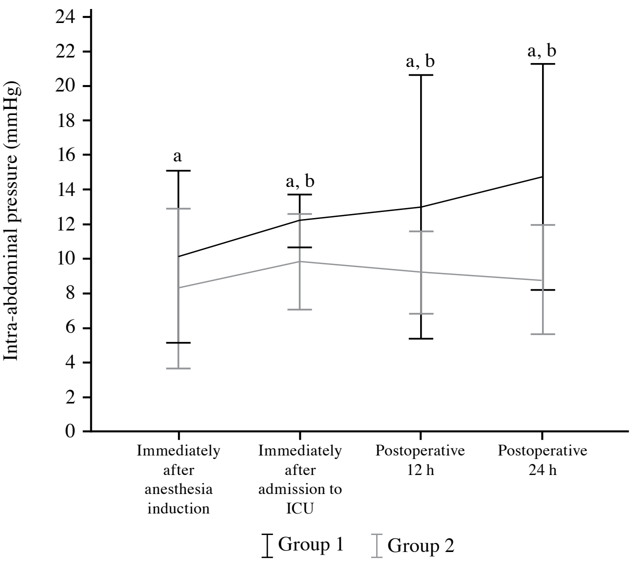

Figure 1. Intra-abdominal pressure values of Group 1 and Group 2. Data are given in mean ± standard deviation.

a: p<0.05 compared between groups in the same period; b: p<0.05 vs. immediately after anesthesia induction within Group 1. There was no significant difference at any time point compared to immediately after anesthesia induction in Group 2.

DISCUSSION

In the present study, we examined IAP changes and factors related to increased IAP during and after cardiac surgery. Our study results demonstrated that cardiac surgery with CPB was a risk factor for increased IAP. In addition, increased IAP was associated with patient characteristics such as age, HT, and intra- and postoperative factors such as duration of CPB, use of blood products, and high lactate levels.

Intra-abdominal hypertension is defined by a sustained or repeated pathological elevation of IAP ≥12 mmHg and abdominal compartment syndrome (ACS) is defined as a sustained IAP of >20 mmHg associated with new organ dysfunction or failure.[10] Common causes are intra-abdominal or retroperitoneal hemorrhage, abdominal surgery, peritonitis, laparoscopy, and pneumoperitoneum, repair of large incisional hernia, massive fluid resuscitation (more than 5 L of fluid/day), ileus, acidosis, hypothermia, sepsis, coagulopathy, and major burns.[11,12] Czajkowski and Dabrowski[2] reported that extracorporeal circulation (ECC) played a role in the development of postoperative IAH and showed an increase in the IAP depending on the degree of hemodilution after the initiation of the CPB. Intensive fluid therapy, particularly with crystalloid solutions, is likely to cause an increase in IAP.[13,14] Andrási et al.[15] demonstrated a significant impact of CPB on the mesenteric circulation in an animal model where CPB causes a splanchnic

Table 4. Univariate and multivariate analysis results

	Univariate			Multivariate		
Variables	OR	95% CI	*p*	OR	95% CI	*p*
Intra-abdominal pressure (baseline)	0.70	0.57-0.86	0.001	0.70	0.50-1.00	0.045
Age	0.95	0.92-0.98	0.004	0.93	0.88-0.99	0.032
Hypertension	4.51	1.94-10.48	0.0001	6.87	1.31-36.02	0.023
Duration of cardiopulmonary bypass	0.97	0.96-0.98	0.0001	0.98	0.95-1.00	0.062
Intraoperative lactate levels	0.53	0.38-0.74	0.0001	0.57	0.34-0.96	0.035
Use of red blood cell	0.24	0.12-0.49	0.0001	0.19	0.06-0.57	0.003
Use of dopamine	0.21	0.08-0.58	0.002	-	-	-
Use of dobutamine	0.28	0.12-0.69	0.005	-	-	-
Use of noradrenaline	0.25	0.08-0.77	0.016	-	-	-
Postoperative lactate levels	0.60	0.45-0.79	0.0001	-	-	-
Duration of cross-clamp	0.97	0.96-0.98	0.0001	-	-	-
Atrial fibrillation	5.89	1.74-18.58	0.004	-	-	-
Acute kidney injury	8.33	0.98-70.48	0.048	-	-	-

OR: Odds ratio; CI: Confidence interval.

hypoperfusion. Hypothermia and rewarming are associated with a release of vasoactive substances, causing vasoconstriction at the microcirculatory level and the gut mucosa, which may lead to bowel edema. Consistent with these findings, there were significant relationship between the increased IAP and duration of CPB in the current study. Yilmaz et al.[16] reported that the higher lactate levels immediately after admission to ICU was a poor prognostic indicator in patients undergoing cardiac surgery. In the present study, higher lactate levels were found in patients with an increased IAP. This finding indicates that patients with increased IAP may have an even worse prognosis

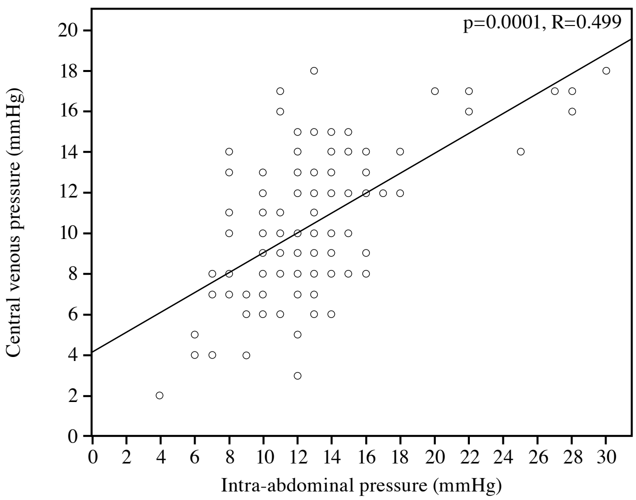

Figure 2. The overall correlation between intra-abdominal pressure and central venous pressure.

with elevated lactate levels. We use crystalloids for the priming of ECC. Our results also suggest that advanced age is risk factors for increased IAP in cardiac surgery. In addition, IAP was high in the patients with preoperatively hypertension and AF. This can be explained by the fact that vascular changes due to hypertension, microembolism, and ischemia may manifest as elevated IAP.

Dalfino et al.[17] reported that baseline IAP values, CVP values, use of vasoactive drugs, fluid balance, AKI, CPB, and age as well as total Sequential Organ Failure Assessment (SOFA) scores were all promoting factors for IAH development in the logistic regression model; however, in the stepwise analysis, baseline IAP value, followed by CVP, and positive fluid balance was the strongest independent predictor of IAH. Also, de Freitas et al.[18] reported that SOFA scores and IAP were not correlated in the ICU patients. Hudorovic and Vicic-Hudorovic[19] found no significant difference in relation to the IAP values and disease severity scores. Nevertheless, Iyer et al.[20] suggested that a nomogram integrating daily IAP, SOFA score, and fluid balance might be used to predict the duration of mechanical ventilation. The SOFA scores were not one of the endpoints of the current study. However, other promoting factors such as baseline IAP values, use of vasoactive drugs, AKI and duration of CPB, and age are consistent with the study of Dalfino et al.[17] In addition, duration of ICU stay was significantly longer in patients with increased IAP in our study.

Intra-abdominal hypertension may cause visceral organ hypoperfusion, intestinal ischemia, as well as bacterial translocation, release of cytokines, and production of free oxygen radicals. All these factors may contribute to the development of multiple organ failure in the critically ill patients.[21-23] The IAH has a global effect on the body, while it affects the renal or gastrointestinal system first. Increased IAP reduces cardiac output, by increasing systemic vascular resistance, pulmonary artery pressure, and pulmonary artery wedge pressure.[3] Also, increased IAP may increase the diaphragm, as well as pleural pressure, inspiratory pressures, and vascular resistance in the pulmonary microcirculation. All these factors also affect the CVP. It can be speculated that, due to the associated increase in the intrapleural pressure, some of the elevations in the CVP may not reflect the intravascular volume precisely.[4,11] It was previously reported that the changes in CVP were correlated with IAP.[3,17] In our study, changes in CVP were found to be correlated with changes in IAP.

Aggressive intraoperative fluid therapy may cause an increase in IAP up to 15 to 25 mmHg.[13] The same result can be seen with ECC and this is the cause of multiorgan failure, particularly in conjunction with the use of inotropic drugs.[17] In our study, we observed no significant difference between the groups according to the positive fluid balance. Our results showed that cross-clamping, ECC, and aortic plaques were other interventions resulting in ischemia, which, in turn, led to increased IAP. Disturbance of hemodynamics that necessitate the use of high-dose inotropes or blood transfusion more than 2 U may predispose to the development of high IAP. This can be resulted from the harmful effects of inotropics on mesenteric circulation and allogeneic transfusion itself.

Acute kidney injury may occur in up to 30% of patients undergoing cardiac surgery. It has been well-known that CPB is an independent risk factor for the development of AKI. Beyazpinar et al.[24] suggested that on-pump beating-heart bypass grafting was superior to conventional coronary artery bypass grafting in terms of AKI, particularly in patients with a serum creatinine level of 1 to 1.3 mg/dL. It was also reported that the IAH was a risk factor for kidney dysfunction.[25] Demarchi et al.[26] found that IAH predicted the occurrence of AKI in patients undergoing abdominal surgeries during the ICU stay and an IAP greater than 7 mmHg had a sensitivity of 87% for identifying patients who developed AKI. Similarly, Dalfino et al.[17] found that the best cut-off value was at 8 mmHg with a sensitivity of 63% and a specificity of 76%. However, Mazzeffi et al.[27] reported that, although the incidence of IAH during the 24 h after cardiac surgery was high, kidney dysfunction was not identified in many patients with IAH according to the RIFLE criteria and, therefore, IAH-related kidney injury might be subclinical and IAH had a low specificity and low positive predictive value for identifying patients who developed kidney dysfunction. In our study, the incidence of AKI significantly increased in patients with IAH.

In their study, Czajkowski and Dabrowski[2] reported that the introduction of IAP measurements to standard monitoring of patients undergoing such procedures might be helpful for earlier diagnosis of renal, hepatic, or intestinal postoperative failure. The simplicity and non-invasiveness of the method is an advantage. Dalfino et al.[17] showed that determinants of IAH should be accurately assessed, and patients presenting risk factors must be monitored properly during the perioperative period. Therefore, in our opinion, the IAP measurement can be used as a standard measure in the monitoring of patients after procedures with ECC. Apart from its diagnostic value, high abdominal pressure may lead to ACS which may be a reason for high morbidity and mortality rates. Early initiation of treatment for IAH currently advocated in view of the possibility of subclinical progress to full-blown ACS.

Currently, some treatments for increased IAP have been recommended.[28] Adequate sedation and analgesia may help to improve abdominal compliance and to decrease IAP. Fentanyl may increase the abdominal muscle tone. Therefore, dexmedetomidine may be preferred instead of fentanyl. Neuromuscular blocking agents may also improve abdominal compliance. Head-of-bed elevation may increase IAP. The anti-Trendelenburg position may be preferred to allow lung recruitment, oxygenation and ventilation, particularly in mechanically ventilated patients. The positive cumulative fluid balance should be avoided. Negative fluid balance would increase abdominal compliance. Diuretics in combination or not with hypertonic solutions such as albumin 20% may be used to obtain negative fluid balance. If the intra-abdominal volume is present, it should be removed via dialysis, ascites drainage, or gastric suctioning. The placement of a nasogastric tube with suctioning with or without gastroprokinetics such as cisapride, metoclopramide, or erythromycin may be used.[28]

Nonetheless, there are several limitations to the current study. First, the findings of this study cannot be generalized to all cardiac surgery patient populations, as the management of surgery and anesthesia may differ by center. Second, results of the treatment protocols for increased IAP were unable to be investigated in this study. Finally, both coronary and valve surgeries were included to the study which may have precluded to obtain precise results.

In conclusion, our study results demonstrated that increased intra-abdominal pressure was associated with baseline intra-abdominal pressure values, age, hypertension, duration of cardiopulmonary bypass, intraoperative lactate levels, and use of red blood cell in patients undergoing cardiac surgery with cardiopulmonary bypass. The detrimental effect of elevated intra-abdominal pressure, which may result in multiple organ failure and mortality, has been recently recognized more frequently in cardiovascular intensive care units. An increased awareness of predisposing risk factors and the addition of intra-abdominal pressure measurement to the standard follow-up scheme, particularly in patients with variable hemodynamics, sensitive abdomen, renal dysfunction, decreased cardiac output, and high lactate levels in the intensive care unit may be effective in early diagnosis of complications and in decreasing morbidity. However, further studies are required to confirm these findings.

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