

The influence of fluid balance on intra-abdominal pressure after major abdominal surgery

Mindaugas Šerpytis, Juozas Ivaškevičius

Clinic of Anesthesiology and Intensive Care, Vilnius University, Lithuania

Key words: *intra-abdominal pressure; intra-abdominal hypertension; fluid balance; systemic inflammatory response syndrome.*

Summary. *Objective. The objectives of this study were to determine the incidence of intra-abdominal hypertension in patients after major abdominal surgery and to evaluate the correlation of intra-abdominal pressure with fluid balance and systemic inflammatory response syndrome.*

Material and methods. This is a prospective observational study. Patients, admitted to intensive care unit after major abdominal surgery, were included into the study. Intra-abdominal pressure was measured via a urinary bladder catheter twice daily. Twenty-four-hour fluid balance and systemic inflammatory response syndrome criteria met by the patients were collected daily.

Results. Seventy-seven patients were included into the study. Intra-abdominal hypertension was diagnosed in about 40% of the patients in the early postoperative period. The study showed a significant positive correlation between 24-hour fluid balance and daily changes in intra-abdominal pressure. A significant association was also seen between the number of positive systemic inflammatory response syndrome criteria and intra-abdominal pressure, and intra-abdominal pressure was significantly higher in patients with systemic inflammatory response syndrome. Besides, patients with intra-abdominal hypertension on the first postoperative day had longer length of stay in the intensive care unit.

Conclusions. Intra-abdominal hypertension occurs commonly in patients after major abdominal surgery, and patients with positive 24-hour fluid balance and/or systemic inflammatory response syndrome are at risk of having higher intra-abdominal hypertension.

Introduction

There is growing evidence that intra-abdominal pressure (IAP) adversely affects almost all organ systems (1) and is a cause of significant morbidity and mortality (2–5). Many risk factors for the development of intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) have been identified in critically ill patients (6). However, several authors have found 24-hour fluid balance and massive fluid resuscitation as well as abdominal surgery to be the independent predictors for the development of IAH (2, 3, 7, 8).

The optimal perioperative fluid replacement strategy is still the subject of debate in the literature (9). Liberal (also defined as standard or aggressive) strategy has been widely accepted in clinical practice due to beneficial effects on cardiovascular function and tissue perfusion (10, 11). However, administration of large amounts of fluid may cause tissue edema. In addition, increased capillary permeability due to systemic inflammatory response syndrome (SIRS), in-

duced by the surgical trauma, also contributes to the distribution of fluid and the development of visceral edema and IAH.

The aims of this study were following: 1) to determine the incidence of IAH in patients after major abdominal surgery, 2) to assess the influence of fluid balance on IAP, and 3) to evaluate the relationship between IAP and SIRS.

Material and methods

This is a prospective observational study conducted in a 12-bed medical/surgical intensive care unit (ICU) Clinics of Santariškės of the Vilnius University Hospital. The study was approved by the Lithuanian Bioethics Committee, and a written informed consent was obtained from the patients enrolled in the study. We included all adult (≥ 18 years) patients who underwent major abdominal surgery and were admitted for more than 24 h to the ICU between August 2005 and January 2006. The exclusion criteria were age of < 18 years, clinical evidence of infection (cholangitis, peritonitis,

or any other intra-abdominal or extra-abdominal infection) because these patients may have exhibited an inflammatory response for infection and not only for surgery, ICU stay <24 h, bladder surgery, pregnancy, severe obesity (body mass index (BMI) of >35 kg/m²; obese patients may have had chronic IAH related to high BMI, as opposed to surgery or visceral edema).

Basic demographic information was registered for all patients on admission to the ICU: age, sex, BMI, date of enrollment, type and duration of surgery. The Acute Physiology and Chronic Health Evaluation (APACHE) II score was calculated using the worst values during the first 24 h of the ICU stay. The following data were recorded on admission to ICU (day of surgery) and on three postoperative days (POD1, POD2, POD3) at 6:00 AM one hour before the day shift in our ICU: 24-hour fluid balance, IAP and SIRS criteria according to ACCP/SCCM (12) met by the patients within 24 h (body temperature of <36°C or >38°C; the heart rate of >90 beats per minute; respiratory rate of >20 breaths per minute or PaCO₂ <32 mm Hg; white blood cell count of <4×10⁹ cells/L or >12×10⁹ cells/L, or >10% immature forms). The 24-hour fluid balance was calculated as the difference between the total 24-hour fluid input and total 24-hour fluid output. The length of stay (LOS) in the ICU was also recorded for all patients. All laboratory analyses were performed routinely in local laboratory of our hospital. All patients had intra-abdominal drains and nasogastric tubes during the study period.

IAP was measured twice daily, and IAH was defined as an IAP of 12 mm Hg or more in at least two consecutive measurements within 24 h. Patients were considered to have SIRS when they had two or more of the SIRS criteria. The patients were assigned to the groups according to the presence or absence of SIRS or IAH.

IAP was measured via the Foley bladder catheter by injecting 50 mL of sterile 0.9% saline into the bladder. IAP was recorded intermittently using a water manometer in the complete supine position at end expiration after ensuring that all air bubbles are carefully removed from the measurement system and IAP respiratory variations are present. Before each measurement, the patient was asked about any abdominal pain, especially when changing position from a semi recumbent to a complete supine one or during the measurement. The patient was also asked to relax and remain still during the measurement to avoid abdominal muscle contractions or tension. The mid-axillary line was used as the zero reference. The IAP was

measured in cm H₂O and then converted to mm Hg (1 mm Hg=1.36 cm H₂O).

Statistical analysis was performed with SPSS for Windows version 11.5 (SPSS Inc., Chicago, IL, USA). A value of P<0.05 was considered statistically significant. Normality of distribution of continuous variables was verified with a one-sample Kolmogorov-Smirnov test. The Pearson correlation coefficient was used to measure the linear relationship between continuous variables for normally distributed data. The differences between groups were assessed using independent-sample t test for normally distributed data and Wilcoxon-Mann-Whitney U test for small sample size or for not normally distributed variables. Chi-square test was used to compare categorical variables and Kruskal-Wallis H test for several independent samples.

Results

We enrolled 77 patients (24 women, 53 men) with a mean age of 62.6±16 years (range, 23–97), mean BMI of 24.6±3.9 (range, 18–34) kg/m², mean operation time of 249±109 (range, 35–570) minutes, mean APACHE II score of 9.88±3.25 (range, 4–19). Table 1 shows the distribution of patients according to type of surgery.

Table 1. Distribution of patients according to type of surgery

Type of surgery	Number	%
Elective/emergency	58/19	75/25
Pancreatic	37	48.1
Gastroduodenal	13	16.9
Colorectal	13	16.9
Hepatic	8	10.4
Small bowel	3	3.9
Splenectomy	2	2.6
Biliary	1	1.3

The mean IAP on admission to ICU was 12.30±2.98 mm Hg, 11.44±3.28 mm Hg on POD1, 10.66±2.87 mm Hg on POD2, and 10.63±2.69 mm Hg on POD3. The incidence of IAH was 45.5 % on POD1, 41.7% on POD2, and 35.6% on POD3.

Fig. 1 illustrates a significant positive correlation between the daily changes in IAP and the daily changes in fluid balance during all three postoperative days. We have observed that a positive fluid balance resulted in an increase in IAP, and contrarily, a negative fluid balance resulted in a decrease of IAP.

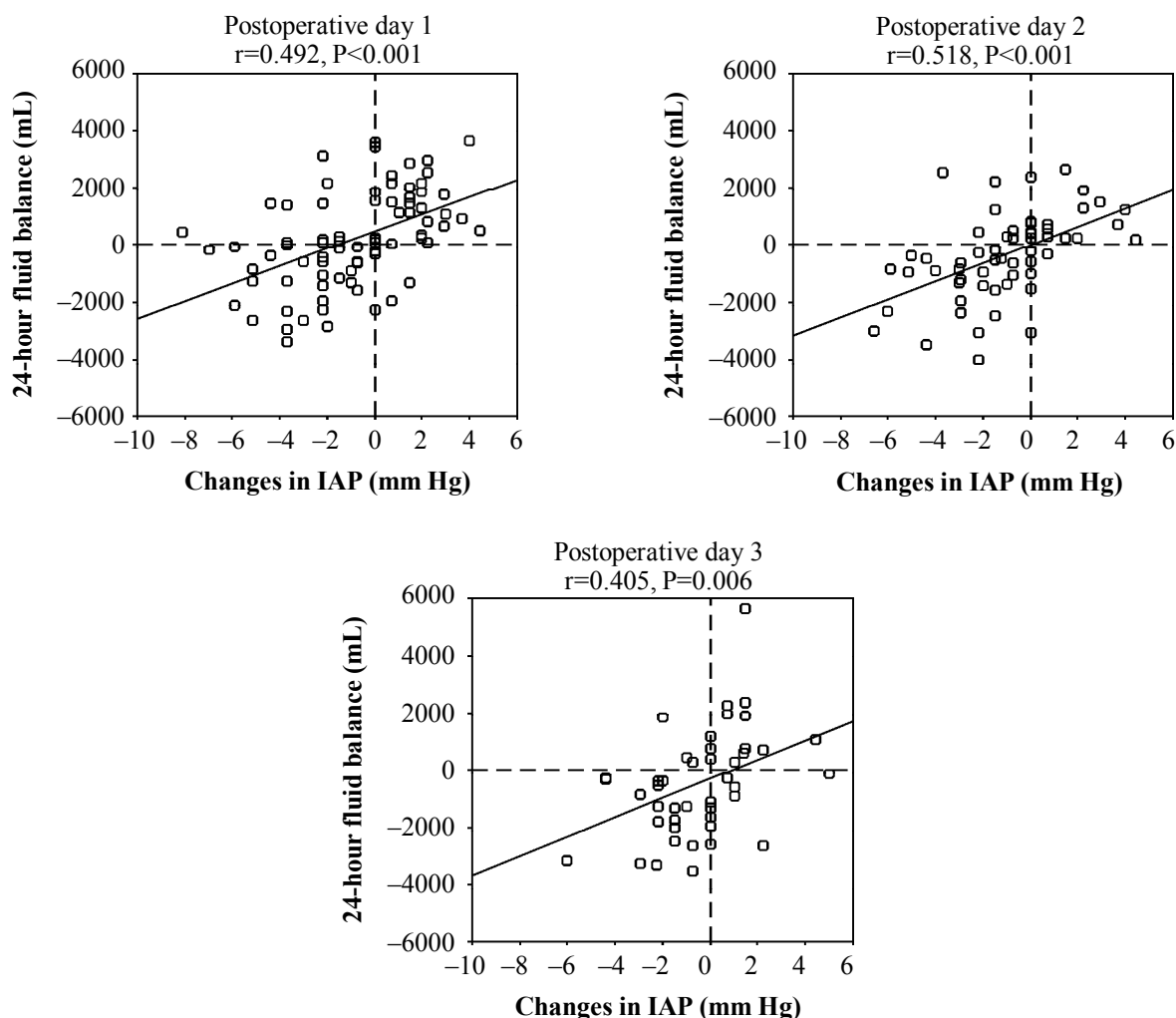


Fig. 1. Pearson correlations between the 24-hour fluid balance and daily changes in intra-abdominal pressure (IAP) on three postoperative days (POD1, POD2, POD3)

Changes in IAP on POD1 represent the difference between IAP on POD1 and IAP on admission to ICU.

Changes in IAP on POD2 represent the difference between IAP on POD2 and IAP on POD1.

Changes in IAP on POD3 represent the difference between IAP on POD3 and IAP on POD2.

The solid line is the regression line; dotted lines are zero reference lines.

Table 2. Cross-tabulation of intra-abdominal hypertension (IAH) and systemic inflammatory response syndrome (SIRS) on three postoperative days (POD1, POD2, POD3)

	POD1*		POD2**		POD3*	
	SIRS	Non-SIRS	SIRS	Non-SIRS	SIRS	Non-SIRS
IAH	27 (61.4)	8 (24.2)	21 (61.8)	4 (15.4)	14 (58.3)	2 (9.5)
Non-IAH	17 (38.6)	25 (75.8)	13 (38.2)	22 (84.6)	10 (41.7)	19 (90.5)

Data were compared by chi-square test: *P=0.001; **P<0.001.

Data are given as numbers of patients; percentages are given in parentheses.

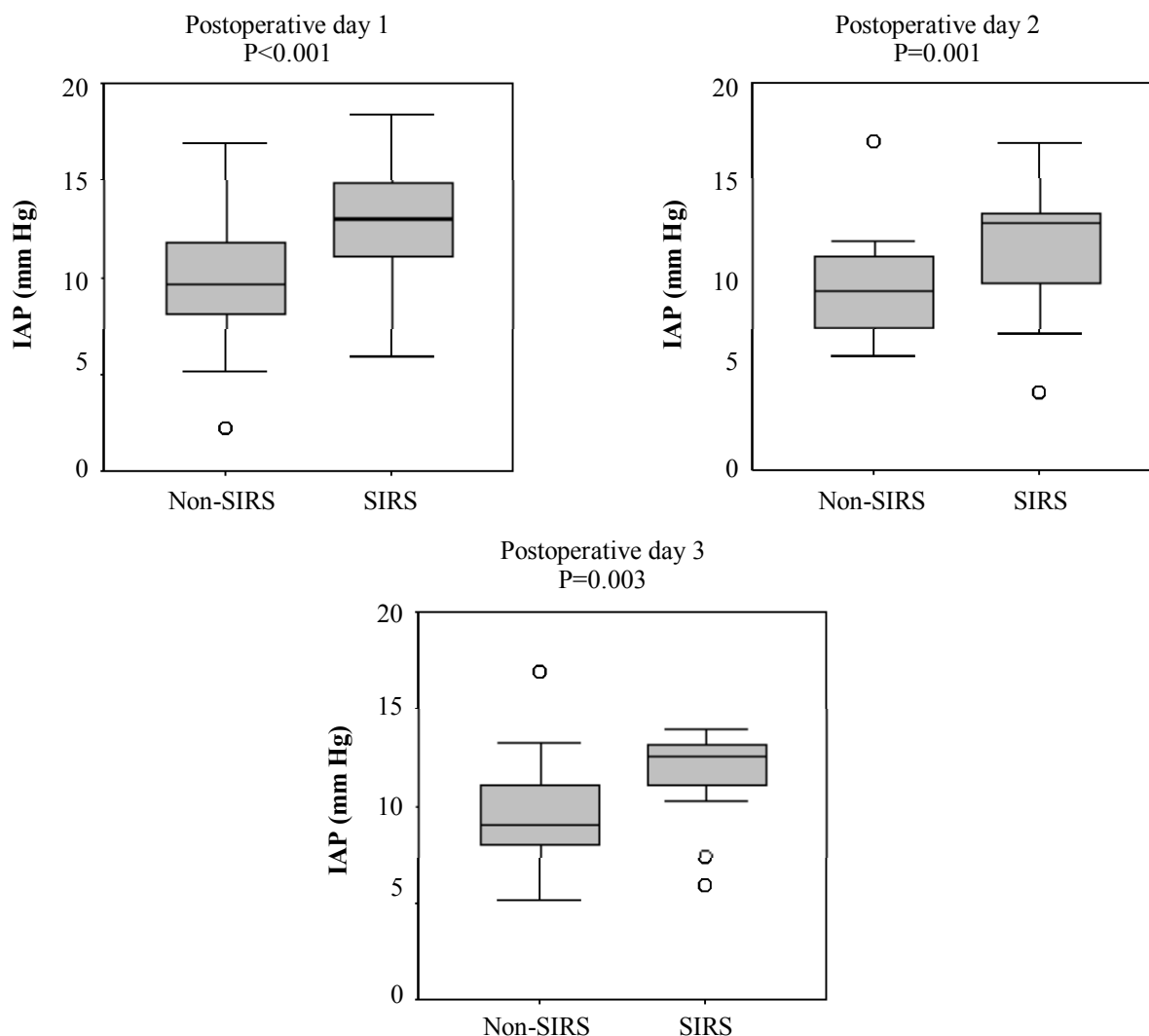


Fig. 2. Intra-abdominal pressure (IAP) in patients with systemic inflammatory response syndrome (SIRS) and without SIRS (non-SIRS) on three postoperative days

The box indicates the 75th and 25th percentiles; the horizontal line within the box indicates the median and the whiskers indicate the 10th and 90th percentiles. Open circles represent outliers.

When the patients were divided into two groups (with SIRS and without SIRS), a significant group difference was found regarding IAP. Fig. 2 demonstrates that IAP was significantly higher in the patients with SIRS. Moreover, results using the chi-square statistics showed that IAH occurred more frequently in patients with SIRS during the entire study period (Table 2). We also revealed a significant dependence between the number of positive SIRS criteria and IAP (POD1 $r=0.386$, $P=0.001$; POD2 $r=0.523$, $P<0.001$; POD3 $r=0.555$, $P<0.001$). The patients with higher number of positive SIRS criteria had also higher IAP during all study days. Besides, the patients with IAH also had a significantly higher number of positive SIRS criteria than the patients without IAH ($P=0.018$ on POD1; $P=0.001$ on POD 2; $P=0.003$ on

POD3).

The median LOS in the ICU for the patients who developed IAH on POD1 was significantly longer compared with the patients who did not (5.0 days [25th to 75th percentile, 4.0 to 7.0 days] vs. 3.0 days [25th to 75th percentile, 2.0 to 4.0 days]; $P<0.001$). Additionally, we analyzed 45 patients who remained in the ICU for the entire three POD. These patients were divided into four groups according to the duration of IAH: patients who did not have IAH at all, and patients who had IAH for 1 day, 2 days, and 3 days. Using Kruskal-Wallis H test, we found the significant positive association between the duration of IAH and LOS in the ICU ($P=0.031$). The patients who experienced IAH for the longer period had longer LOS in the ICU.

Discussion

Fluid therapy remains one of the most controversial issues in perioperative management (9). Conflicting data exist regarding restrictive or liberal strategy of perioperative fluid replacement on postoperative complications and recovery of gastrointestinal tract (13, 14–17). Liberal strategy of perioperative fluid administration includes replacement of preoperative fluid deficit, replacement of “third space” losses, preloading the patient before regional anesthesia, replacement of blood and insensible losses, maintaining an optimal central venous pressure, blood pressure and urine output, *etc.* The liberal fluid therapy may result in the mean volume of fluids administered on the day of surgery up to 6 L, on postoperative days up to 4 L (13, 14). Eventually, the mean total fluid input on the fourth postoperative day may reach up to 8 to 18 L (13, 17). On the other hand, the surgical stress-induced release of aldosterone, antidiuretic hormone as well as activation of renin-angiotensin system lead to sodium and water retention (18, 19). Furthermore, the release of inflammatory mediators in response to surgical trauma results in SIRS, increased capillary permeability, and water shift from intravascular compartment into the interstitial space. Thus, the liberal clinical practice of fluid therapy may result in a perioperative weight gain of about 3–4 kg (13, 14). Even in healthy volunteers, the administration of 40 mL/kg of lactated Ringer’s solution resulted in a weight gain of median 0.85 kg persistent 24 hour after infusion (20). Peripheral edema, which is usually seen after major abdominal surgery and liberal fluid administration (13), is external manifestation of increased capillary permeability and over-hydration; however, one could only speculate about edema of internal organs within abdomen. IAP might be considered as the mirror of things that happen inside the abdomen. Any enlargement of internal organs due to edema as well as accumulation of ascites/blood or bowel distension increase IAP after abdominal surgery. Visceral edema due to massive fluid infusion is well known in trauma patients (5, 7, 8). Moreover, in a mixed population critically ill patients Malbrain *et al.* showed that fluid resuscitation >3.5 L was the independent predictor of IAH (2). However, there are only a few studies on that issue regarding surgical population. Biancofiore *et al.* found that liver transplant recipients who developed IAH received significantly higher amount of fluids (5420±1073 vs. 2852±905 mL/day (P<0.01)) as well as red blood cell transfusions (21), but they did not calculate the fluid balance. Only one study analysed the influence of 24-hour fluid balance on IAP in exclusively surgical popu-

lation. This was a retrospective case-matched study, which found in multivariate analysis that patients who developed ACS had significantly higher 24-hour fluid balance (15.9±10.3 L vs. 7.0±3.5 L, P<0.05) (3). However, they included patients only with ACS which was defined as IAP >25 mm Hg, with oliguria and increased peak airway pressure, and did not analyze the influence of daily 24-hour fluid balance on daily changes in IAP. The main finding of our study was a significant correlation between 24-hour fluid balance and daily changes in IAP. We revealed that the positive fluid balance resulted in an increase in IAP and in opposite negative fluid balance led to a decrease in IAP. We showed that IAP reacts sensitively to daily changes of fluid balance in patients after major abdominal surgery, and patients with positive fluid balance are at risk of having higher IAP.

In recent years, more and more cases of ACS are reported in trauma patients without abdominal injury (22–24) as well as in burn patients (25). This syndrome was termed as a secondary ACS (SACS) (6). It is well recognized that the main pathophysiological mechanism of this syndrome is increased capillary permeability due to SIRS. Surgery is also commonly accompanied by SIRS and increased capillary permeability. We found that patients with SIRS had higher IAP, and IAH was more frequently diagnosed in the patients with SIRS. However, it is noteworthy that there are some data from animal model studies that increase in IAP may induce cytokine production and promote SIRS (26, 27).

In addition, we found that the patients who experienced IAH on POD1 had a longer LOS in the ICU. This is in accordance with McNelis *et al.* study, where patients with ACS had a significantly longer LOS in the surgical ICU compared with patients without ACS (10.4±11.3 vs. 3.8±2.3 days, P<0.001) (3). However, it was not proved in patients after liver transplantation (21).

Despite an increasing amount of studies on the IAH and ACS, the question about the incidence of IAH/ACS remains unanswered due to the different definitions of IAH/ACS and not uniform IAP measurement technique via the bladder used in studies. Different studies used different thresholds (13, 15, 20, and 25 mm Hg) to define IAH. According to consensus definitions proposed by WSACS, IAH is defined by a sustained or repeated pathological increase in IAP ≥12 mm Hg (6). However, only two multicenter epidemiological studies used the threshold of 12 mm Hg or more to define IAH (2, 28). In one-day study authors found that 58.8% of the patients had IAH (28). In another study with the higher amount of mixed ICU patients, IAH was observed in 32.1% of the patients

(2). We also used a cut-off value of 12 mm Hg and found a similar high rate of IAH in the patients after major abdominal surgery (about 40%).

A limitation of this study, however, was instillation volume used to measure IAP. The instillation volume for intermittent IAP measurement used in different studies varies significantly from 50 to 250 mL. However, De Waele *et al.* revealed that the minimal volume required to transmit the pressure signal was 10 mL (29). Recently, Malbrain and Deeren gradually increasing instillation volumes found that the actual IAP may be overestimated with instillation volumes over 50 mL and the volume up to 25 mL is sufficient (30). This volume is now recommended by WSACS (6). However, there are no studies to date using this volume. In both multicenter epidemiological studies performed by Malbrain *et al.* (2, 28) as well as in our study, the instillation volume was 50 mL; therefore, the real incidence of IAH may be overestimated. A study based on the definitions and standardized IAP measurement techniques as proposed by WSACS is warranted.

Conclusions

Intra-abdominal hypertension occurs frequently in patients after major abdominal surgery and is associated with longer length of stay in an intensive care unit. This study shows a close positive correlation between fluid balance and intra-abdominal pressure. Moreover, patients who have systemic inflammatory response syndrome are at risk of having higher intra-abdominal pressure. Therefore, these findings suggest that intra-abdominal pressure should be monitored routinely in the early postoperative period, especially in patients who achieved positive fluid balance and/or have systemic inflammatory response syndrome.

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Skysčių balanso įtaka intraabdominaliniam spaudimui po didelės apimties pilvo operacijų

Mindaugas Šerpytis, Juozas Ivaškevičius

Vilniaus universiteto Anesteziologijos ir reanimatologijos klinika

Raktažodžiai: intraabdominalinis spaudimas, intraabdominalinė hipertenzija, skysčių balansas, sisteminis uždegiminio atsako sindromas.

Santrauka. *Tikslas.* Nustatyti intraabdominalinės hipertenzijos dažnį ligoniams po didelės apimties pilvo operacijų ir įvertinti intraabdominalinio spaudimo koreliaciją su paros skysčių balansu ir sisteminiu uždegiminio atsako sindromu.

Tyrimo metodai. Atliktas prospektyvusis ligonių po didelės apimties pilvo operacijų, gydytų intensyvosios terapijos skyriuje, tyrimas. Intraabdominalinis spaudimas buvo matuotas per kateterį šlapimo pūslėje. Kasdien buvo skaičiuojamas paros skysčių balansas ir sisteminio uždegiminio atsako sindromo kriterijai.

Rezultatai. Ištirti 77 ligoniai. Intraabdominalinė hipertenzija diagnozuota 40 proc. ligonių ankstyvuoju pooperaciniu laikotarpiu. Nustatyta statistiškai reikšminga teigiama koreliacija tarp paros skysčių balanso ir intraabdominalinio spaudimo pokyčių. Statistiškai reikšmingas ryšys rastas ir tarp sisteminio uždegiminio atsako sindromo kriterijų skaičiaus ir intraabdominalinio spaudimo, o ligoniams, kuriems buvo diagnozuotas sisteminis uždegiminio atsako sindromas, nustatytas didesnis intraabdominalinis spaudimas. Be to, tyrimas parodė, kad ligonių, kuriems pirmą pooperacinę parą buvo nustatyta intraabdominalinė hipertenzija, gydymo trukmė intensyvosios terapijos skyriuje buvo statistiškai reikšmingai ilgesnė.

Išvados. Intraabdominalinė hipertenzija yra dažna ligoniams po didelės apimties pilvo operacijų. Ligoniams, kuriems nustatytas teigiamas paros skysčių balansas ir (ar) sisteminio uždegiminio atsako sindromas, yra didesnė intraabdominalinės hipertenzijos rizika.

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