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ORIGINAL ARTICLE

Intraabdominal Pressure in Children After Cardiothoracic Surgery

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Summary

Introduction. Intraabdominal pressure (IAP) now is widely recognized as an important variable and its monitoring is used in a variety of critically ill patients.

Aim of the study. The aim of this study was to measure and to recognize the influence of various factors on IAP in children after surgical correction of congenital heart disease.

Materials and methods. We conducted non-randomized, prospective observational study in Pediatric intensive care unitat a University Children's hospital. Study protocol was approved by Hospital Ethics commision. Measurements of IAP were performed in 15 children with mean body weight 8±5,83 kg, (Range 3,1-28 kg), mean age of 18,01 months (range 8 days-8 years) after cardiothoracic surgery. Cardiopulmonary bypass (CPB) was used in 12 patients. IAP was measured during first 24 hours postoperatively at 12 hour intervals via indwelling urinary catheter with bladder volumes of 1 ml/kg of normal saline. Of the 15 patients, 12 were mechanically ventilated at the time of the IAP measurements. Ventilation pressures: PIP (peak inspiratory pressure), MAP (mean airway pressure), PEEP (positive end expiratory pressure) and central venous pressure (CVP) via femoral vein were recorded. In some patients (6 from 15) amount of fluid evacuated via intraperitoneal drain from peritoneal cavity in first 24 hours was measured.

Results. IAP was 12,24±3,54 mm Hg (Range 5,44-20,4 mm Hg), CVP 13±2,19, PIP 20±2,48 cm H2O, MAP 9±2,3 cm H2O, PEEP 5±1,35 cm H2O. Amount of fluid removed from peritoneal cavity during first 24 hours was 0,8±0,54 ml/kg/h (Range 0,04-1,7 ml/kg/h).

Conclusions. We find elevated intraabdominal pressure (IAP>12 mm Hg) in 10 from 15 (66,67%) pediatric patients in the first 24 hours after cardiothoracic surgery.

There was a difference in IAP in patients with abdominal paracenthesis versus patients without the drain. The difference between groups was not statistically significant (P=0,4). We did not find a correlation between IAP, MAP and CVP. We, however, did not observe development of abdominal compartment syndrome (ACS).

Key words: intraabdominal pressure; intraabdominal hypertension; abdominal compartment syndrome; cardiothoracic surgery.

INTRODUCTION

The impact of elevated IAP were described in the 19th century but were only recognized as a significant problem in surgical adults in the 1980s. However, since the 1940s pediatric surgeons have observed multisystem organ failure associated with increased IAP following primary closure of congenital abdominal wall defects and were the first to use prosthetic materials for abdominal decompression (1). In 1989, Fietsam et al. (2) introduced the term "abdominal compartment syndrome" (ACS) to describe the pathophysiological effects of increased IAP. The authors reported four patients who developed oliguria, hypoxia, hypercapnia, increased PIP, and increased CVP associated with massive abdominal distension in the postoperative period of ruptured abdominal aortic aneurysms. Over the last decade, ACS has been increasingly diagnosed in critically ill patients, which has coincided with a significant increase in the number of publications related to this topic. Recently, a group of critical care specialists convened at the second World Congress on ACS and developed consensus definitions and guidelines for the diagnosis and treatment of IAH and ACS. In healthy individuals, a normal IAPis 5 to 7 mm Hg according to the consensus definition of the World Society of Abdominal Compartment Syndrome (WSACS, http://www.wsacs.org/). The upper limit of IAP is generally accepted to be 12 mm Hg by the World Society (3). Clinical conditions that can lead to IAH are well known in pediatrics. Life-threatening IAH has been well described in neonates born with gastroschisis and omphalocele, when primary closure of the abdominal defect was attempted, resulting in decreased thoracic compliance and in hemodynamic compromise (4). Surgical techniques currently used to treat ACS, like temporary abdominal closure with synthetic materials and staged abdominal repair, were pioneered in these patients (5). IAH and its effects also were described in children with major burns (6), resulting in poorer prognosis. Clinical presentation of ACS is similar to adults, but children may develop ACS at a lower IAP (as low as 16 mm Hg) (7). Direct IAP measurement is impractical in most situations and the most common method is an indirect measurement via the bladder, a technique that has been validated (8) and which correlates well with IAP (9).

Number of studies are devoted to describe cardiovascular effects of elevated IAP. IAH leads to a reduction in cardiac output (CO). Although this effect may be seen with IAP as low as 10–15 mmHg, it is most consistently seen at an IAP greater than 20 mmHg (10,11). The decrease in CO is related to diminished venous return, increased peripheral resistance, or increased intrathoracic pressure. Venous return is reduced by a number of mechanisms (12). Increased IAP leads to reduction in caval and retroperitoneal venous flow. Venous flow is also reduced by functional narrowing of the inferior vena cava at the suprahepatic, subdiaphragmatic level, where the high pressure zone of the abdomen meets the lower pressure zone of the thorax. Elevation of peripheral vascular resistance is likely to be related to mechanical compression of capillary beds. IAH increases intrathoracic pressure by elevating the diaphragm. As a result, ventricular filling pressure increases while ventricular compliance decreases. All these factors (diminished venous return, increased peripheral resistance, and increased intrathoracic pressure) lead to a reduced stroke volume with compensatory increase in heart rate. The blood pressure usually remains unchanged (13).

AIM OF THE STUDY

The aim of this study was to measure IAP and to recognize relationship of various factors (CVP, variables during mechanical ventilation, amount of fluid accumulated in the abdominal cavity) on the IAP in pediatric patients after surgical correction of congenital heart disease. We hypothesized that IAP in patients after cardiothoracic surgery is close to normal range.

MATERIALS AND METHODS

We conducted non-randomized, prospective observational study in Pediatric Intensive care unit at the University Children's Hospital. Study protocol was approved by Hospital Ethics commision. Measurements of IAP were performed in 15 children, with mean body weight of 8±5,83 kg, (Range 3,1-28 kg), mean age of 18,01 months (range 8 days-8 years) after the surgical correction of congenital heart disease. (Fig. 1). Surgical interventions, performed on patients, are summarized in Table 2. Cardiopulmonary bypass (CPB) during operative procedure was used in 12 patients. IAP was measured during first 24 hours postoperatively at 12 hour intervals via indwelling urinary catheter in supine position with bladder volumes of 1 ml/kg of normal saline. The end of the catheter was connected to transparent, open ended plastic tubing, and the level of the water column above the midaxillary line reflects IAP. Of the 15 patients, 12 were mechanically ventilated with Avea (Viasys Respiratory Care Corp., USA) and Evita 4 (Dräger Medical, Lübeck Germany) ventilators in a pressure control mode to keep patients blood gases within normal range. Ventilation pressures: PIP (Peak inspiratory pressure), MAP (Mean airway pressure), PEEP (Positive end expiratory pressure) and central venous pressure via femoral vein (Fig.2) simultaneously with IAP were recorded. To avoid ventilation induced lung injury and to ensure normal venous blood return to right heart PIP was limited to 25 cm H_2O and PEEP to 5-7 cm H_2O. In some patients (6 from 15) to prevent fluid accumulation in abdominal cavity peritoneal paracenthesis was performed intraoperatively and catheter was connected to reservoir. Amount of fluid evacuated via catheter from the abdominal cavity in the first 24 hours was measured. Descriptive statistics for mean, standard deviation and range were used to describe the sample. Coeficient of determination (r^2) was used to determine the relationship between two variables. Significance level $P<0,05$ was considered statistically significant. Statistical analyses were performed using Microsoft Excell Data analysis tool.

RESULTS

In our study group IAP was 12,24±3,54 mm Hg (Range 5,44-20,4 mm Hg). Majority of patients (60%) had IAP in the range of 12-20 mmHg, one third of children (5-33%) had normal IAP (<12 mmHg), only one patient had abdominal hypertension, sligtly exceeding 20 mmHg (Fig.6.). CVP was measured via femoral vein catheter with its tip in the inferior v. cava (IVC), mean CVP was 13±2,19 mmHg, PIP 20±2,48 cm H_2O, MAP 9±2,3 cm H_2O, PEEP 5±1,35 cm H_2O. Amount of fluid removed from peritoneal cavity during first 24 hours was 0,8±0,54 ml/kg/h (Range 0,04-1,7 ml/kg/h). (Table 1). The difference in IAP between children without catheter inserted in abdominal cavity and those who had peritoneal drainage was not statistically significant (P=0,4, Fig. 5). Our study demonstrates a weak inverse correlation between IAP and MAP (Fig.3) and weak positive correlation between IAP and CVP, measured in the IVC via femoral vein (Fig.4).

DISCUSSION

We did not expect such a large number of patients (66,67%) with elevated (>12 mmHg) IAP and that finding did not confirm our initial hypothesis**.** It is difficult to determine precisely the direct cause of IAP elevation. The complicated flow pattern during CPB as well as intra- and postoperative therapy may result in such pathology. Nevertheless, hemodilution and inflammatory response, which induce tissue oedema, seem to be the most important factors. Recently, the effect of normovolemic blood dilution during CPB was documented (14). Moreover, aggressive fluid resuscitation was associated with an increase in gut permeability, which leads to intestinal edema (15). Interestingly, the beginning of CPB results in decreased colloid osmotic pressure, increased microvascular permeability and increased capillary pressure (16). Several authors demonstrated that CPB induced the inflammatory reaction, which led to tissue oedema. According to Tassani et al. (17), who analyzed the microvascular protein escape before and after newborn cardiac procedures, CPB 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 (18) reported the inflammatory response at the beginning of CPB. 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 (17,18).

There is also some controversy with regard to the effect of mechanical ventilation and the use of PEEP on IAP. Expansion of the abdominal cavity from elevated IAP results in a cephalad displacement of the diaphragm with reduction in dynamic pulmonary compliance and a requirement for increasing PEEP to deliver the same tidal volume. Sussman (19) was the first to look at the effects of PEEP on IAP and showed in their experiment that increasing PEEP to 15 cm of H_2O did not affect the IAP. This was confirmed by Guimaraes and animal data (20). However, on increasing PEEP to 15 cm of H_2O, others have found only a mild increase in IAP in patients with a baseline IAP below 12 mmHg (21). Further, in patients with a baseline IAP above 12 mmHg, the effect of PEEP seems to be more pronounced (22). Our patients were ventilated in "protective mode" with limited PIP to avoid lung overdistension, volutrauma and ventilation-induced lung injury, PEEP was limited too, in order to minimize effect of increased intrathoracic pressure to right atrial filling (23). Therefore our study did not show any influence of ventilation variables on IAP.

In 6 patients (from 15) to prevent fluid accumulation in abdominal cavity peritoneal paracenthesis was performed intraoperatively. Percutaneous catheter drainage of free intraabdominal fluid, air, abscess, or blood is an effective technique for reducing IAP and potentially correcting IAH-induced organ dysfunction (24, 25). Percutaneous decompression can significantly reduce IAP and decrease morbidity of surgical decompression. Removal of even small volumes of fluid can significantly lower IAP (26). This minimally invasive approach to IAH/ACS management is most effective in patients with secondary ACS due to excessive fluid resuscitation, burns, acute pancreatitis, or ascites (27).

CONCLUSIONS

We find elevated intraabdominal pressure (IAP>12 mm Hg) in 10 from 15 (66,67%) pediatric patients in the first 24 hours after cardiothoracic surgery.

There was a difference in IAP in patients with abdominal paracenthesis versus patients without the peritoneal drainage**.** The difference between groups was not statistically significant (P=0,4).

We did not find correlation between IAP, MAP and CVP, measured in the IVC. We, however, did not observe development of abdominal compartment syndrome.

Preemtive abdominal paracenthesis in children after cardiac surgery prevents fluid accumulation and uncontrolled rise in IAP, leading to ACS.

Conflict of interest: None

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Table 1.

Summary of results

Variables	Mean	Range	SD
Age, months	18,01	14 days-8 years	±24,08
Weight, kg	8,93	3,1–28	±5,83
IAP mm Hg	12,3	5,44–20,1	±3,54
CVP (via femoral vein), mm Hg	12,68	10–19	±2,19
PIP cm H_2O	19,17	15–23	±2,48
MAP cm H_2O	9,28	6–15	±2,30
PEEP cm H_2O	5,06	4–6	±1,35
Fluid removal, ml/kg/h	0,88	0,04–1,7	±0,63
IAP (mm Hg) in non- ventilated pts	13,87	9,52–20,4	±4,13
IAP (mm Hg) in ventilated pts	11,86	5,44–17,68	±3,36
IAP (mm Hg) in pts with drain	11,79	5,44–20,4	±4,08
IAP (mm Hg) in pts w/o drain	13,6	6,8–17,68	±3,85
Abbreviations: IAP-intraabdominal pressure, CVP-central venous pressure, PIP-peak inspiratory pressure, MAP-mean airway pressure, PEEP-positive end expiratory pressure			

Table 2.

Operative procedures

Type of surgical intervention	No of pts.
Coarctation of the aorta repair	2
Patient ductus arteriosus ligation	1
Tetralogy of Fallot repair	2
Atrial septal defect closure	2
Ventricular septal defect closure	6
Atrioventricular septal defect closure	2
Total:	15

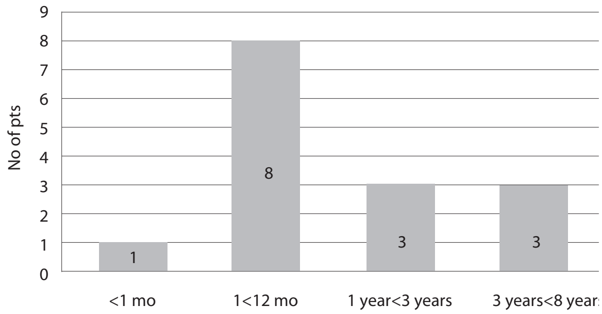

Fig. 1. Age of patients

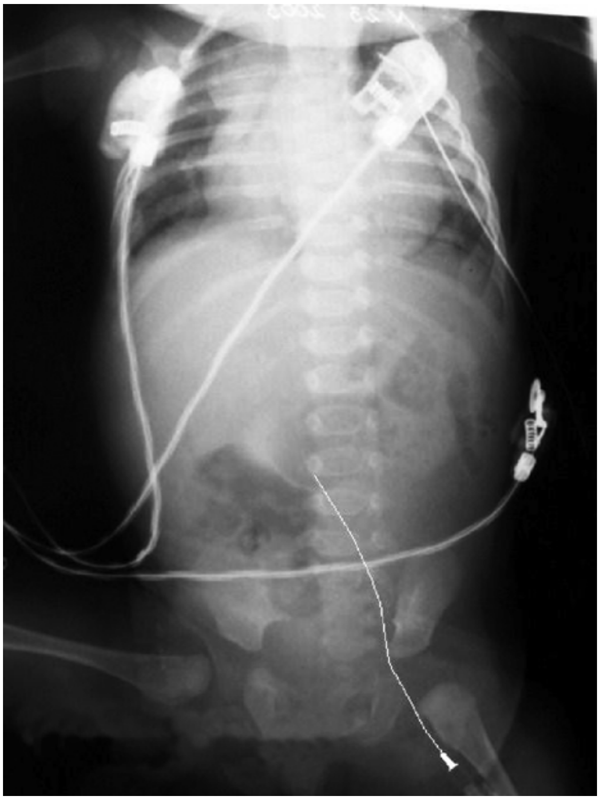

Fig. 2. Catheter passed through femoral vein with its tip in the inferior v. cava

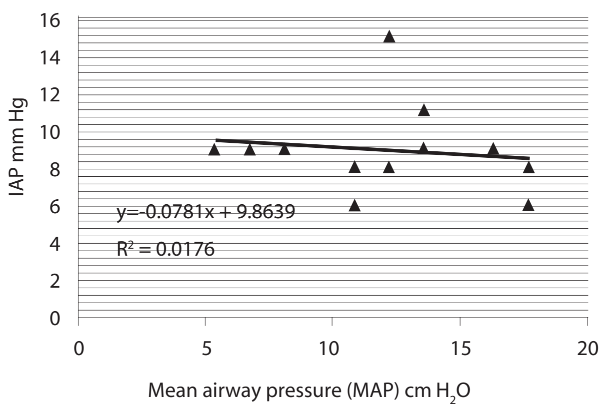

Fig. 3. MAP versus IAP

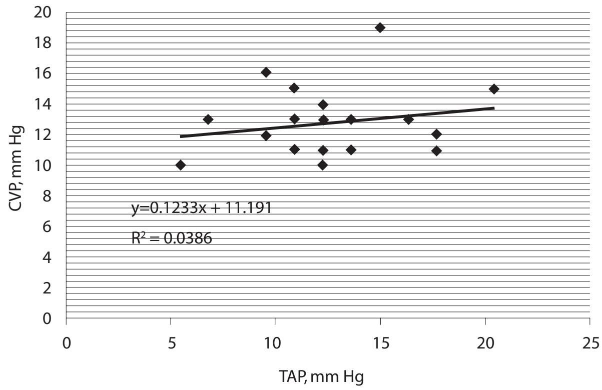

Fig. 4. CVP versus IAP

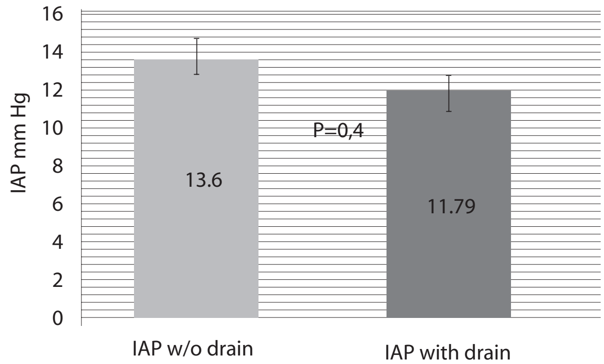

Fig. 5. Abdominal decompression and IAP

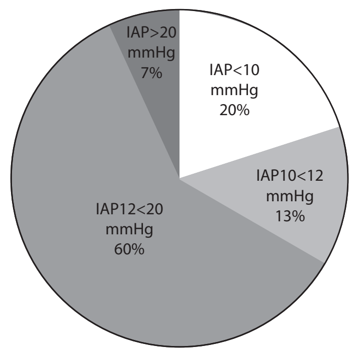

Fig. 6. Patients grouped by IAP level