UTILITY OF MEASUREMENTS OF ABDOMINAL PERFUSION
PRESSURE AS A MEASURE OF ISOVOLEMIC STATUS AND
INTESTINAL PERFUSION IN PATIENTS WITH RUPTURED AORTIC
ANEURYSM

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Ruptured abdominal aorta aneurysm of ten results in intraabdominal hypertension (IAH). When IAH exceeds 20 mm Hg, intestinal ischemia can result that is a common cause of severe postoperative complications, including death. **The aim of the study** was to evaluate utility of measurement of abdominal perfusion pressure (APP) to estimate intestinal perfusion and isovolemic status in patients undergoing surgical treatment for ruptured abdominal aorta aneurysm.

**Material and methods.** A group of 40 patients of either sex, aged 47 – 93 years (average age 70 ± 10) was treated at an Intensive Care Unit after surgical reconstruction of abdominal aorta due to ruptured aortic aneurysm. The study was prospective. The following were measured: parameters of intraabdominal pressure (intraabdominal pressure – IAP, abdominal perfusion pressure – APP); parameters of intestinal perfusion – tonometric (intramucosal gastric carbon dioxide partial pressure PgCO₂, intramucosal-arterial difference in carbon dioxide partial pressure – Pg-aCO₂); hemodynamic parameters (mean arterial pressure – MAP, central venous pressure – CVP).

**Results.** A statistically significant correlation was demonstrated between parameters of visceral perfusion and abdominal perfusion pressure. Pearson correlation coefficient for APP/PgCO₂ and APP/Pg-aCO₂ was negative and was – 0.4664 and – 0.3498, respectively.

**Conclusions.** Abdominal perfusion pressure is an useful parameter in the evaluation of intestinal perfusion in IAH patients after surgical treatment of ruptured aortic aneurysm. MAP reflects current physiological body reserves at a critical stage of the disease, informing about possibility to provide visceral perfusion and indirectly, about adequacy of fluid replacement therapy. In intraabdominal hypertension, CVP is falsely elevated, making it of low utility in the evaluation of volemic status and intestinal perfusion.

**Key words:** intraabdominal pressure, abdomen compartment syndrome, ruptured aortic aneurysm, large intestinal ischemia

Despite enormous progress in the treatment of patients with ruptured aortic aneurysm, postoperative mortality remains high and ranges from 18 to 50% (1, 2). This adverse outcome is related to high intraoperative mortality and numerous postoperative complications leading to multi organ dysfunction syndrome (3, 4). This condition is usually preceded by signs and symptoms of hypovolemic shock and postoperative increase of intraabdominal pressure (IAP) (5, 6, 7). Prolonged persistence of intraabdominal pressure exceeding 12 mm Hg results in intraabdominal hypertension (IAH), which favors development of abdomen compartment syndrome (ACS).
According to consensus of international experts, ACS is diagnosed when the following criteria are met: IAP exceeds 20 mm Hg and there are symptoms of one of vital systems (cardiovascular-respiratory, urinary or alimentary) (8). Intraabdominal hypertension and abnormalities of intestinal perfusion are closely interrelated, they facilitate one another, being a “flywheel” of MODS development. In response to a potent physiological stimulus that is dehydration and hypovolemic shock, early necrosis of intestinal villi develops, later resulting in transmural intestinal injury (9-12). These changes develop particularly rapidly in patients who underwent aortic or cardiac surgery, in the elderly who often suffer from chronic cardiovascular disease. Perioperative period in patients with ruptured aortic aneurysm is an ideal example of postoperative IAP increase and its sequela, in particular abnormalities of volemic status and impaired intestinal perfusion. Relevance of these parameters for adequate postoperative management has not yet been fully understood (13). Therefore monitoring of these changes can have a significant effect on early prevention of intestinal ischemia and improvement of treatment results.

The aim of the study was to evaluate prognostic utility of: intestinal perfusion parameters, measurement of intraabdominal pressure, abdominal perfusion pressure and central venous pressure in the assessment of isovolemic status and intestinal perfusion in patients undergoing surgical treatment for ruptured abdominal aorta aneurysm.

MATERIAL AND METHODS

The study group included 40 patients of either sex, aged 47 – 93 years (average age 70 ± 10 years) undergoing surgical reconstruction of abdominal aorta due to ruptured aortic aneurysm. The surgical procedure involved suturing of a simple graft (aorto-aortic graft) with end-to-end anastomosis in the proximal and distal segment or bifurcated graft with end-to-side anastomosis of its branches with iliac or femoral arteries. To obtain a relatively homogeneous study group, the study enrolled patients whose postoperative treatment at an Intensive Care Unit (ICU) exceeded 24 hours, while those who died within 24 hours after the treatment were excluded from the study.

Before the start of any procedure, each patient had inserted:
1) an intravenous cannula to a forearm vein,
2) an intraarterial cannula to the radial artery following a negative result of Allen test,
3) 3-way catheter to a central vein following cannulation of the right jugular vein or the venous angle,
4) Intragastric tonometric TRIP® probe, Tonometrics (Finland),
5) 3-way catheter to the urinary bladder (18 G, Kendall).

The following tonometric parameters were measured in patients qualified for the study to optimize hemodynamic parameters and adequacy of fluid replacement therapy:
1. Parameters of intraabdominal pressure:
   – intraabdominal pressure (IAP),
   – abdominal perfusion pressure (APP = MAP – IAP),
   (APP – abdominal perfusion pressure; MAP – mean arterial pressure);
2. Parameters of intestinal perfusion:
   – intramucosal gastric carbon dioxide partial pressure (Pg CO₂),
   – intramucosal-arterial difference in carbon dioxide partial pressure (Pg-aCO₂ = PgCO₂ – PaCO₂),
   (PaCO₂ – arterial carbon dioxide partial pressure);
3. Hemodynamic parameters:
   – mean arterial pressure (MAP),
   – central venous pressure (CVP).

These parameters were measured at the patient admission to the Department and then every 6 hours until hour 72 of treatment at ICU. This was aimed at selection of the study group, homogeneous with regard to number of measurements and length of therapy.

Intraabdominal pressure (IAP) was measured using Kron’s technique modified by Malbrain, according to additional authors’ modification. For this purpose a 3-way Foley catheter inserted to the urinary bladder was used. One of the channels was connected with an urine bag, another channel was connected, with an adapter (Vygon REF. 801.00), to a conventional set for invasive pressure measurement with a transducer. The patient was supine, lying on his/her back. After emptying the urinary bladder, the catheter channel that was connected with an urine bag, was closed with a clamp. Then 100 ml 0.9% NaCl was addend from the drip infusion set connected
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to the pressure measuring set to patient’s urinary bladder with a syringe. After equilibration of the set at the level of pubic prominence (mid-axial line), intraabdominal pressure was read at the end of patient exhalation and the clamp was released, therefore allowing free outflow of previously infused saline. Our modification involved use of a 3-way Foley catheter that allowed direct communication between pressure measuring set and urine bag without the need of use of Y adapter 7x7x7 mm, Porgès, France).

Concurrently with IAP, intramucosal gastric carbon dioxide partial pressure (PgCO₉) was measured and then used to calculate intramucosal-arterial difference in carbon dioxide partial pressure. PgCO₂ was measured with a tonometric probe TRIP®, Tonometrics (Finland) and Tonocap™, Datex-Ohmeda (Finland), which was an air tonometer. The principle of operation of this tonometer is based on fully automated measurement that involves filling a balloon located at the end of the probe with air and then collecting a sample of air from the balloon and measuring PgCO₂. After an initial, approximately 20 – 30 minute equilibration period when CO₂ equilibrated with intramucosal CO₂, subsequent measurements were repeated automatically every 10 minutes. Tonometric probe, which is a modified nasogastric probe, was inserted under anesthesia. Adequate position of the probe in the stomach was confirmed intraoperatively by a surgeon. Patients received proton pump inhibitors to eliminate interference of gastric juice with measurement of PgCO₂. Furthermore pH of gastric juice was measured daily to rule out errors in measurement of PgCO₂. Hemodynamic parameters were measured using a M&A Athena monitoring system, Denmark. Biochemical parameters were measured using Mascott apparatus, United Kingdom.

Statistical methods

Parameters with normal distributions were tested with t-test for independent variables for differences between the two groups (deceased/recovered). Parameters without normal distribution were tested with a non-parametric Mann-Whitney test. Correlations between PgCO₂, Pg-aCO₂, IAP, and APP were tested using Pearson correlation coefficient for the whole study group and in the groups of deceased and recovered patients. Statistical hypotheses were verified at the p ≤ 0.05 level. Calculations were done using a statistical software STATISTICA v. 6.0 and Analyse – it v. 1.71.

RESULTS

Thirty per cent (12/40) of the study patients died during the treatment at ICU. One (3.6%) patient died within 30 days after the surgical procedure in the group of patients that survived the procedure (70%, 28/40). The patient died on day 14 after the transfer to department of surgery as a complication of reoperation for failure of peripheral anastomosis of the left branch of the graft as a result of infection. Autopsy demonstrated an extensive myocardial infarction. Due to the specifics of the complication and fact that this complication occurred after completion of treatment at ICU, the patient was qualified to the group of recovered patients.

Parameters of intraabdominal pressure:

– Intraabdominal pressure (IAP). Average IAP during the first three days of patient hospitalization in the department were significantly different in the two study groups (fig. 1).

– Abdominal perfusion pressure (APP). Average APP in day two and three of patient hospitalization in the department were significantly different in the two study groups (fig. 2).

Parameters of intestinal perfusion:

– Intramucosal gastric carbon dioxide partial pressure (PgCO₂). There were no significant
differences in PgCO₂ between the two study groups (fig. 3).

- Intramucosal-arterial difference in carbon dioxide partial pressure (Pg-aCO₂).

There were no significant differences in Pg-aCO₂ on day one of patient hospitalization in the department between the two study groups (fig. 4). Significant difference in average Pg-aCO₂ between the two study groups appeared on day two. These values fell in the “warning zone” (10 – 20 mm Hg) in the group of deceased patients.

Correlations between parameters of intestinal perfusion (PgCO₂, Pg-aCO₂) and parameters of intraabdominal pressure (IAP, APP):

- A statistically significant correlation was demonstrated between parameters of intestinal perfusion and parameters of intraabdominal pressure. Pearson correlation coefficient for IAP and PgCO₂ was positive and was 0.2091. Correlation IAP/Pg-aCO₂ was characterized by a coefficient of 0.013. Pearson correlation coefficient for APP/PgCO₂ and APP/Pg-aCO₂ was negative and was -0.4664 and -0.3498, respectively.

Hemodynamic parameters:

- Mean arterial pressure (MAP). MAP was normal in both study groups during the first three days of patient hospitalization in the department. However statistically significant differences between the two study groups were observed on day two and three.

- Central venous pressure (CVP). Average CVP during the first three days of patient hospitalization in the department differed significantly between the two study groups. Due to different duration of ventilation and statistically significant differences in IAP between the study groups, interpretation of inter-group differences seems unwarranted.

DISCUSSION

Intestinal ischemia rate after elective reconstruction of abdominal aorta is 1 – 3% (9). Surgical procedures for rupture of aortic aneurysm increase this rate from 7 to 10% (9). Despite this, according to Björck (13), occurrence of this complication may only be a „tip of the iceberg”. According to this author, intestinal ischemia is much more common. In particular in cases of ruptured aortic aneurysms. One can suspect that postoperative mortality results mainly from this complication along with chronic IAH (6, 9). This is supported by observations by Sugrue that indicate that over 40% of abdominal surgical procedures done
under extreme conditions, are accompanied by IAH (14). Because IAH along with abnormalities of intestinal perfusion can indicate multidisciplinary failure, we attempted to evaluate prognostic utility of parameters of intraabdominal pressure and parameters of visceral perfusion in patients following reconstruction of abdominal aorta due to ruptured aneurysm.

Taking into consideration data from the literature concerning quantitative assessment of IAH, we identified three levels of intraabdominal pressure in our material. IAH defined as IAP > 12 mm Hg was present during the first three days of treatment in 50% of patients operated due to ruptured abdominal aorta aneurysm. If the upper normal limit for IAP was 15 mm Hg, then IAH could be diagnosed in 27% of the study group. IAP exceeding 20 mm Hg was found in one patient during this time. According to Malbrain and co. in multi-center studies (CIAH- Critically Ill and Abdominal Hypertension), IAP > 12 mm Hg was a valuable prognostic factor of development of multiple complications (8). This is also supported by our study. From the practical point of view, observation of IAP changes during the first three days of treatment can be of prognostic relevance (5). Increase of IAP (diAP), defined as a difference of average IAP on day 3 and 1 and on day 2 and 1 in patients who died on day 2 of treatment at ICU differed significantly in the group of deceased and recovered patients. We observed an increasing trend in both study groups.

We must also emphasize that observed differences in IAP increase were statistically significant in both study groups. However, according to Cheatham, APP has higher prognostic sensitivity and specificity (15). According to this author APP = 50 mm Hg provides adequate visceral perfusion and separates good from adverse prognosis. Our results from the first three days of patient hospitalization at ICU indicate that the highest sensitivity and specificity was achieved at APP=70 mm Hg. As with diAP, also dAPP results achieved in both study groups differed significantly. There was a decreasing trend in APP in the deceased group and increase in the recovered group. Because two interrelated variables affect APP, i.e. MAP and IAP and furthermore the same MAP and IAP values can have different (adverse) effect in different subjects depending on general condition. This indirectly indicates importance of maintenance of adequate visceral perfusion due to maintenance of correct MAP.

In patients with ruptured abdominal aorta aneurysm hypovolemia occurs resulting in constriction of visceral blood vessels and reduction of oxygen supply (6, 8, 16). This results in tissue acidosis which can be recorded with gastric tonometry by measuring intramucosal pH (pHi). Maynard et al. evaluated prognostic utility of gastric tonometry and found that pHi 24 hours after surgical treatment of a ruptured abdominal aorta aneurysm was significantly higher in the recovered group versus the deceased group (17). Gys et al. obtained opposite results in his group of 59 patients (18). To avoid discrepancy in results, currently measurement of PgCO$_2$ and Pg-aCO$_2$ (i.e. result of regional CO$_2$ production (PgCO$_2$) and amount CO$_2$ reaching the intestines (PaCO$_2$) is recommended as a measure of visceral hypoperfusion (19). We did not find any statistically significant differences in PgCO$_2$ between the two patient groups at critical time points during the procedure. As with PgCO$_2$, there were no statistically significant differences both in average Pg-aCO$_2$ as well as with regard of increase of this parameter over the first three days of treatment.

However, when we analyzed data from the deceased patients, we found an increasing tendency of PgCO$_2$ and Pg-aCO$_2$ to pathological levels but this was too late to be of prognostic utility. Maybe analysis of larger group of patients would provide data with both clinical and statistical significance.

Maintenance of average MAP above 80 mmHg provided high efficacy of resuscitation management (fluid replacement therapy, electrolyte support) in both study groups. This value in combination with cardiac index (CI) > 2.5 l/min/m$^2$ provided adequate intestinal perfusion in IAH patients (8). Therefore MAP reflects current physiological reserves of the body at the critical stage of the disease.

Central venous pressure (CVP) reflects intravascular volume with adequate function of cardiovascular system. CVP is falsely elevated in IAH and therefore of little utility. This results from interrelationship between CVP and PCWP generated due to increase of IAP with increased thoracic pressure and impaired venous return.
CONCLUSIONS

Measurement of intraabdominal pressure is a valuable prognostic tool in a group of patients after surgical treatment of ruptured abdominal aorta aneurysm. MAP reflects current physiological body reserves at a critical stage of the disease, informing about possibility to provide visceral perfusion and indirectly, about adequacy of fluid replacement therapy. In intraabdominal hypertension, CVP is falsely elevated, making it of low utility in the evaluation of volemic status and intestinal perfusion.

REFERENCES