Haemodynamic Changes after Minimal-Invasive Surgical Operations

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Abstract: ***Modern medicine is increasingly beginning the use of not only laparoscopic but also robotic operations. Mini-invasive operations create a prerequisite for lower frequency of a number of unwanted effects that are common encountered in conventional surgery. However, the induction of CO_2 in the abdominal cavity creates a prerequisite for the onset of a number of hemodynamic complications that are potentially dangerous for the life of the patient. Therefore, their timely recognition and the way they are mastered is of utmost importance for the best way out of anesthesia and surgery.***

Keywords: hemodynamic changes, robotic surgery, laparoscopic surgery, complications

1. Introduction

According to the International Association for the Study of pain, it is unpleasant sensory and emotional condition caused by the action of an actual or possible damaging effects on tissues. (1)

It is not surprising that modern surgical techniques aim minimal invasiveness, through which is achieved lower degree of pain and post-operative complications. In modern medicine, more and more are not used only laparoscopic but also robotic operations. (2)

Mini-invasive operations create a prerequisite for lower frequency of a number of adverse effects occurring in conventional surgery. (3)

It is also considered suitable for patients with high BMI, as minimal-invasive technique reduces the risk of infections, as well as the severity of the operative trauma. (4)

Due to the small trauma, excellent visibility of the operative field, a good cosmetic effect, faster recovery and return to everyday activities, that kind of surgery is becoming increasingly widely used for the treatment of many diseases. (5), (6), (7), (8), (9), (10), (11), (12)

It has been shown that in the application of laparoscopic and robotic operations, the intensity of pain in the early postoperative period is 1-4 by VAS (Visual Analogue Scale), regardless of the type of painkillers, which proves the minimal invasive character of both surgical methods. (13)

Despite all these advantages, robotic and laparoscopic operations also hide some risks for patients. This is more common observed in robotic operations.

At the beginning of robotic operations, an intra-abdominal pressure is created up to 20 mmHg, as a result of which the large vessels in abdominal cavity are compressed. (14)

This pressure during pneumoperitoneum includes several pathophysiological mechanisms, regardless of the species of the gas used.

The most important mechanisms are the neuro-humoral responses: secretion of vasopressin and the activation of renin-angiotensin-aldosterone system in response to the stress and the reflexes of n. Vagus. (15), (16), (17), (18),(19).

There are number of cardiovascular changes that occur due to the mechanical and chemical effects of CO_2 induced pneumoperitoneum. (20)

Although laparoscopic surgery is well tolerated by most patients, cardiovascular changes may have adverse effects on patients with limited cardiac reserve. Numerous studies have documented the impact of CO_2 induced pneumoperitoneum on haemodynamic variables. In most studies, were reported increases of mean arterial pressure and decrease or absence of changes in the heart rate and the heart work. (22), (23)

These changes are proportionable to the changes in intra-abdominal pressure, more often when the patient is in position 15 ° Trendelenburg. (24) Most frequently reported changes are connected to the haemodynamics.

In 1997, Jungas and coll. came to the conclusion that the effect of the increased intraabdominal pressure on haemodynamics depends on the magnitude of the extra (above normal) increased intraabdominal pressure, the disorder of hemodynamic volume of circulating fluid (intravascular condition) and the baseline of haemodynamics. (25)

Therefore, changes in hemodynamic parameters in mini-invasive operations can be determined by different factors: intraabdominal pressure level, duration of the pneumoperitoneum, the patient's position on the surgical table, the rate of accumulation of CO_2 in arterial blood ($PaCO_2$) and hypercapnia (Pet CO_2), the presence or absence of cardiacvascular pathologies, etc. (26), (27), (28), (29)

According to Diabel et al., if the intraabdominal pressure does not exceed 10 mmHg, the mean haemodynamics in general remain normal, but there is a significant decrease of the arterial blood flow in the liver. High intraabdominal pressure (more than 14 mmHg), causes changes in external breathing function and rotation of the heart as a result of displacement of the diaphragm, which increases the overall pulmonary resistance and decrease in the functional capacity of the lungs. (30), (31)

The effect on systemic hemodynamics has a two-phase nature. At first there is a certain increase in the heart volume and heart rate, b.c. increasing venous return to the right part of the heart from the organs in the abdominal cavity. Later on the cardiac flow and the heartbeat decrease as a result of the pressure on capacitive vessels in the abdominal cavity, and this leads to increased vascular resistance. Insufflation of gas in the abdominal cavity causes disturbance of local haemodynamics - compression occurs in v.cava inferior with disruption of the circulation in its pool, blood flow disorder in the arteries and veins in the abdominal cavity and retroperitoneal space. (32), (33)

Increased intraabdominal pressure also leads to mechanical obstruction in the venous return of the blood, resulting increased blood flow pressure in the veins of the lower limbs and decrease of the preload of the left ventricle.

All these mechanisms increase the systemic vascular resistance, leading to increase of the heart afterload. The development of hemodynamic changes depends on the functional reserve of the myocardium: reduction of the heart flow and arterial hypotension are possible without increasing the heart rate. (34), (35)

Joris et al. (1995), using invasive monitoring, proved that after peritoneal insufflation (8-12 mmHg), there is significant increase in mean arterial pressure (by 35%), increase of systolic vascular resistance (65%) and pulmonary vascular resistance (by 90%), as well as reduction of heart rate index (by 20%) until central venous pressure is increased. (36)

Several studies have concluded that it is increased systemic vascular resistance that leads to decreased heart rate. (37)

According to Darlon Vanlong and colleagues, there is no change in heart rate at the time of CO 2 insufflation and the formation of the pneumoperitoneum.

They reported a significant decrease in mean arterial pressure after two hours of onset of the pneumoperitoneum compared to the baseline. (38)

Similar results have reached Meininger and coll. (39)

However, in a study by Fabella et al. Meininger et al proves a significant increase of mean arterial pressure after insufflation of CO_2. (40), (41)

Both studies compared mean arterial pressure with the post-induction values.

At the same time, all measured parameters are returned to baseline values (prior to pneumoperitoneum) 10-30 minutes after the pneumoperitoneum, and more are not affected by postural changes or desalination of gas from the abdominal cavity. (42)

The Darlong study noted a significant decrease in peripheral vascular resistance and cardiac index after the induction, after the pneumoperitoneum and immediately after positioning the patient at 45 ° Trendelenburg.

After induction with Thopental and Isoflurane-Fentanyl anesthesia, there is decrease in hemodynamic performance. In the end of the laparoscopy, this team of authors describes the return of the central venous pressure to its baseline level.

Hirvonen and call. report a reduction in peripheral vascularity resistance and impact volume after induction and after CO_2 -pneumoperitoneum and positioning the patient at 45 ° Trendelenburg. (43)

Lin and call. (2013), in a study prove that hemodynamic changes can be reduced when the pneumoperitoneum is induced while the patient is on the operative table on his back before being placed in Trendelenburg or reverse-Trendelenburg. (44)

In a study by Golubeva and call. (2012) with the help of the variable pulsometry was found that during the pneumoperitoneum the original normotonia is replaced before desuflation with sympathicotonia, which reflects the activation of adaptation mechanisms. Later on it turns into growing vagotonia, which testifies of the collapse of the adaptation mechanisms.

It was found that the peak of the arrhythmogenic effect of the pneumoperitoneum occurs in the period immediately before desulflation of gas from the abdominal cavity and lasts up to 15 minutes. The authors conclude that the pressure level of pneumoperitoneum that causes the corresponding hemodynamic effects depend on the patient's individual characteristics, therefore maintaining intra-abdominal pressure during laparoscopy in level of 8-10 mmHg is not safe. (45)

One of the most common complications described in the pneumoperitoneum are hypertension, hypotension and arrhythmia.

According to Umar and call. and Gut and call. these changes are more common at first of gas insufflation in normotonic patients. (46), (47)

It has been proved that CO_2 more than any other gases insufflated in the abdominal cavity causes pulmonary hypertension, as in prolonged operations this effect increases. (48)

As a result, the CO_2 -induced pneumoperitoneum occurs activation of the sympathetic nervous system with the release of catecholamines in the blood which leads to vasoconstriction, increased heart rate, increased arterial pressure and arrhythmia. (49)

It is possible to develop different types of arrhythmia: sinus tachycardia and ventricular extrasystoles due to released catecholamines, bradyarrhythmia (sinus bradycardia, nodal rhythm, atrioventricular rhythm, asistolia), which is associates with rapid peritoneal insufflation of CO_2 (50), (51), (52), (53), (54), (55), (56)

Vigorous vasovagal response due to rapid insuflation of peritoneum or in the event of gas embolism may lead to heart arrest. (57), (58), (59)

To avoid or minimize these effects of pneumoperitoneum, most authors recommend:
1) Preoperative infusion therapy (up to 10 ml / kg). Otherwise, the combination of high intra - abdominal pressure with bending head down to Trendelenburg position can cause a significant reduction in cardiac index (up to 50%).(60), (61), (62), (63), (64), (65), (66)
2) Pneumatic compression of the lower limbs effectively increases venous return and cardiac overload. (67)
3) Low rate of gas supply when applying pneumoperitoneum (≤ 5 l / min) is important both for reducing the possibility of fatal consequences of gas embolism (in case of accidental intravascular induction of gas) and to exclude vasovagal reflexes leading to arterial hypotension, arrhythmia and cardiac arrest. (68)
4) It is recommended to use the lowest level of intra-abdominal pressure in each case. It is accepted, that the main stages of laparoscopic surgery are possible at intra-abdominal pressure of 5-7 mmHg. (69), (70)
5) The European Society of Endoscopic Surgeons (EAES), also recommends using as low pressure as possible in the abdominal cavity when performing laparoscopic operations. (71)
6) Extreme positions of the operation table should be avoided, except the short episodes needed for the implementation of the individual stages of the operatio. (72)

2. Conclusion

Minimal invasive surgical techniques are widely used in various surgical areas. It is related to the advantages that this kind of surgery provides, which are : weak pain, short hospital stay and good cosmetic effect.
However, the induction of CO_2 into the abdominal cavity creates a prerequisite for number of haemodynamic complications that are potentially dangerous to the patient's life. That’s why, their recognition and the way they are treated are of utmost importance for the good outcome of anesthesia and operative intervention.

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