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IMPROVEMENT OF CEREBRAL OXYGENATION DURING LAPAROSCOPY USING INTERMITTENT SEQUENTIAL COMPRESSION OF LEGS

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A b s t r a c t: The creation of CO_2 pneumoperitoneum during laparoscopy causes a series of adverse effects. Impairment of brain oxygen saturation during laparoscopy is a result of increased intra-abdominal pressure, absorbed CO_2 and increased intracranial pressure.

The aim of this study is to investigate the possible effects of pneumatic intermittent sequential compression (ISC) of legs on oxygenation of the brain during laparoscopy.

100 patients, ASA groups 1 and 2, subjected to elective laparoscopic cholecystectomy, were included in this study. The patients were divided into two groups consisting of 50 patients each, group I, control group, and group II, where ISC was applied. Oxygen saturation of the mixed venous blood from the internal jugular vein ($SjvO_2$) is an indirect assessment of cerebral oxygen use (oxygenation of the brain). Blood samples were obtained from the bulb of the right jugular vein, as the dominant side for venous drainage from the brain. Informed consent was obtained from each patient. Blood samples of 2 ml were obtained several times during the operation; the first sample immediately after anesthesia induction in order to establish the baseline values of $SjvO_2$, the second sample immediately after the creation of the pneumoperitoneum, and then every 15 minutes respectively until the end of the pneumoperitoneum. The last sample was obtained before the extubation of the patients. The ISC in group II was terminated after obtaining the last blood sample.

Results showed that the average values of oxygen saturation of the mixed venous blood from the internal jugular vein – $SjvO_2$ levels were higher in group II where ISC was applied (82.3% → 86.4% → 85.3% → 80.2% → 82.8% → 80.4%), compared to group I, without ISC (85.5% → 77.8% → 80.6% → 83.8% → 84.8%), statistically significant in the second and third measurement for $p < 0.05$ for the second and the third measurement, i.e. after the creation of pneumoperitoneum, when the decreease in the brain oxygenation is most dramatic in the group without ISC.

In conclusion, application of intermittent sequential compression of the legs is a simple and safe technique for preserving the brain oxygenation during laparoscopy by restoring the blood return from the legs.

Key words: laparoscopy, brain oxygenation, intermittent sequential compression.

Introduction

Laparoscopic surgery has been a widely accepted surgical technique for the last two decades. Its popularity among both patients and doctors has contributed to the low rate of morbidity and mortality associated with this surgical technique, which justifies the term "minimum invasive surgery" referring to endoscopic surgery [1, 2]. The advantages of laparoscopic surgery compared to classical laparotomy are well known: a lower systemic immune stress response due to the lesser tissue destruction, shorter duration of postoperative ileus, lower use of antibiotics and analgetics, shorter duration of hospital stay, rapid recovery and return to normal activities, better economic effect and superior cosmetic effect [3, 4, 5, 6].

Although in the outcome of laparoscopic surgery total morbidity and mortality rates are lower compared to classical laparotomic procedures, it is a lesser known fact that there are some considerable risks for the patients during laparoscopic interventions. These risks originate from the positioning of the patient during the operation, the pneumoperithoneum created by insufflation of carbon dioxide under pressure in the abdominal cavity causing increased abdominal pressure, and the effects of the insufflated carbon dioxide [7, 8, 9, 10].

These factors cause a series of changes in some physiological functions during the laparoscopy and in the immediate postoperative period. Changes to the haemodynamic, respiratory volumes and capacities, biochemical changes of the blood and changes in cerebral haemodynamic and oxygenation are most prominent and of greatest clinical significance [7, 8, 9, 10, 11]. These changes to physiological functions pose a serious threat to the patient's health and to the surgery's outcome, especially in those patients who already have coexisting diseases of the cardiovascular, respiratory or central nervous system.

Several studies conducted on animals and humans have shown that pneumoperitoneum causes an increase of the intracranial pressure due to the elevated intra -abdominal pressure, which causes elevated central venous pressure, leading to reduced venous drainage from the central nervous system [12, 13, 14]. Further elevation of the intracranial pressure is due to the effects of the absorbed carbon dioxide, which causes vasodilatation of the cerebral blood vessels, expanding the vascular compartment of the brain and leading to further elevation of the intracranial pressure [14, 15, 16]. Oxygen delivery in the brain is dependent on the perfusion of the brain, which is dependent on the intracranial pressure; therefore the changes to the intracranial pressure during laparoscopy lead to a decreasing of the perfusion and oxygenation of the brain [16, 17].

Pneumatic intermittent sequential compression (ISC) of the legs is a simple and efficient method for improvement of the haemodynamic by improving venous blood return from the legs, which is compromised during laparoscopy [18].

The aim of this study is to investigate the possible effects of pneumatic intermittent sequential compression of the legs on oxygenation of the brain during laparoscopy.

Methods

Patients

Study participants were recruited from the patients at the University Digestive Surgical Clinic for and the University Clinic for Anaesthesiology, Reanimation and Intensive Care Medicine (from April 2009 to July 2010). 100 patients (65 females, 35 males), aged between 30 and 60, were enrolled in the study according to the following criteria: all the patients were subjected to elective laparoscopic surgical removal of the gall bladder, according to ASA (American Society of Anesthesiologist) they belonged to groups 1 and 2.

ISC application and measurement of brain oxygenation

The patients were randomly divided into two groups: group I,the control group, consisting of 50 patients, and group II, also consisting of 50 patients, where the pneumatic intermittent sequential compression (ISC) of the legs was applied. The compressions of the legs were sequential and gradual, under a pressure of 45 mmHg above the ankle, 40 mmHg below the knee, and 35 mmHg above the knee via the SCD Express^{TM} system with vascular refill detection. The ISC was applied after the anaesthesia induction, and was terminated immediately after the termination of pneumoperitoneum. Pneumoperitoneum was created by insufflation of carbon dioxide into the abdominal cavity under s pressure of

12–14 mmHg. The patients were induced in general anaesthesia by a standardized induction: Midazolam 0.1 mg per kg body weight, Fentanyl 0.005 mg per kg body weight, Rocuronium bromide 0.6 mg per kg body weight and Propofol 2 mg per kg body weight. The patients were intubated and mechanically ventilated with 12 breaths per minute and a tidal volume of 10 ml per kg body weight with a mixture of 40% oxygen and 60% nitrous oxide, and 1MAC Sevoflurane.

Oxygen saturation of the mixed venous blood from the internal jugular vein ($SjvO_2$) is an indirect assessment of cerebral oxygen use (oxygenation of the brain). Clinical measurements of $SjvO_2$ reflect the balance between the oxygen delivery and oxygen consumption of the brain. Simply, when demand exceeds supply, the brain extracts greater oxygen, resulting in decreased jugular bulb oxygen saturation [19]. Blood samples were obtained from the bulb of the right jugular vein, as the dominant side for venous drainage from the brain [19, 20]. Informed consent was obtained from each patient. Blood samples of 2 ml were obtained several times during the operation: the first sample immediately after the anaesthesia induction in order to establish the baseline values of $SjvO_2$, the second sample immediately after the creation of pneumoperitoneum, and then every 15 minutes until the end of the pneumoperitoneum. The last sample was obtained before the extubation of the patients. The ISC in group II was terminated after obtaining the last blood sample. The blood gas samples were analyzed in the AVL compact gas analyser.

Statistical analyses

Data analysis was performed using the Statistical Package for Social Sciences (SPSS) for Windows, version 15.0. The following tests were used: percent of structure for sex, mean and standard deviation for numerical data such as age as well as for the values of $SjvO_2$. The Mann-Whitney U test was used in order to test the differences of the mean values of $SjvO_2$ between the two groups, and the statistical significance was set at $p < 0.05$.

Results

There were 65 females (35 in the group without ISC, and 30 in the group with ISC) and 35 males (15 in the group without ISC and 20 in the group with ISC) whose mean age was 47.5 years in the group without ISC, and 46 years in the group with ISC.

Average values of the oxygen saturation of the mixed venous blood from the internal jugular vein – $SjvO_2$ (cerebral oxygen saturation) levels were higher in the group II where ISC was applied compared to group I, without ISC (Table

1, Graph 1 and Graph 2, Graph 3). The average value of $SjvO_2$ after the anaesthesia induction in the group without ISC was 85,5%. Reduction of the value of $SjvO_2$ from 85.5% to 77.8% was recorded immediately after the creation of the pneumoperitoneum. In further measurements, there was a tendency to recovery of the cerebral oxygen saturation (85.5 → 77.8 → 80.6 → 83.8 → 84.8), but still the values of $SjvO_2$ did not reach the basic values even after the termination of the pneumoperitoneum (Table 1, Graph 1).

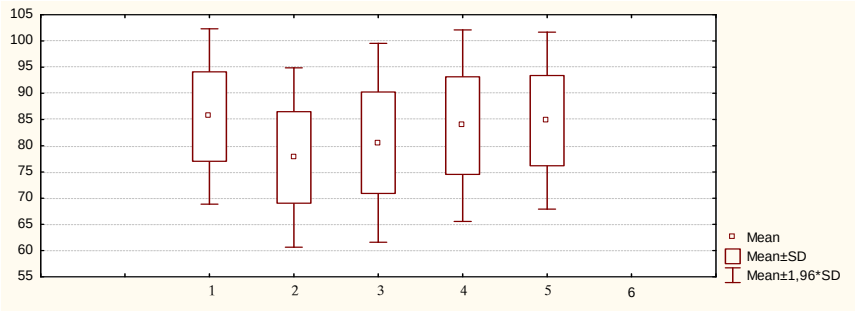
The average value of the $SjvO_2$ after the anaesthesia induction in the group with ISC was 82.3%. There was increase of the value of $SjvO_2$ in the second measurement, after the application of ISC and creation of the pneumoperitoneum up to 86.4%. In further measurements, there were variations of the average values of $SjvO_2$ (82.3 → 86.4 → 85.3 → 80.2 → 82.8 → 80.4) (Table no. 1, Graphic no. 2). The highest average value of $SjvO_2$ (86.3%) in the group with ISC was registered in the second measurement, i.e. after the application of ISC and creation of pneumoperitoneum, while the lowest average value of $SjvO_2$ (77.8%) was registered.in the group without ISC, in the second measurement, after the creation of pneumoperitoneum,

The differences in the average values of $SjvO_2$ between the two groups according to the Mann-Whitney U test are statistically significant for the second and third measurements of $p < 0.05$. Although there are differences in the values between the groups in the other measurements as well, they did not reach the statistical significance of $p < 0.05$.

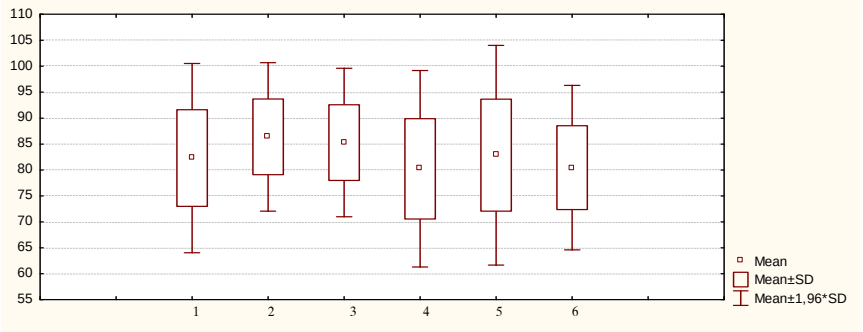
Table 1

Average values of $SvjO_2$ in both group of patients

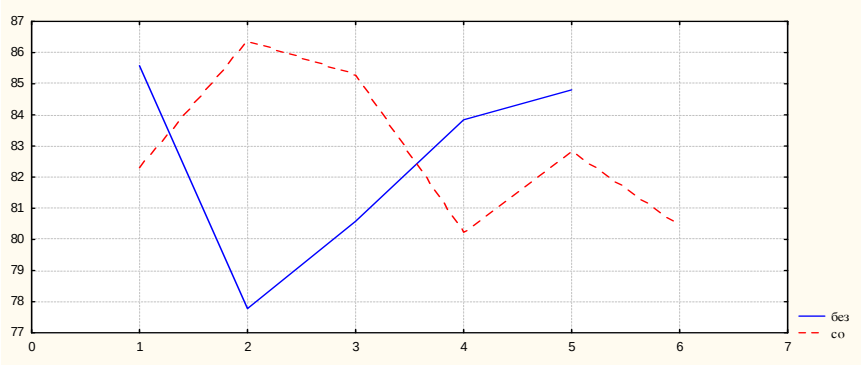
Group	$SvjO_2$	Number	Medium	Minimum	Maximum	± St Dev
I No ISC	1	50	85.578	68.9	99.1	8.532968
	2	50	77.774	64.0	93.4	8.728883
	3	50	80.582	67.3	97.1	9.680122
	4	30	83.84	55.0	97.4	9.324073
	5	5	84.8	69.4	89.0	8.611330
II With ISC	1	50	82.2980	64.6	95.5	9.30224
	2	50	86.37	70.5	98.9	7.29818
	3	50	85.278	68.8	99.6	7.29826
	4	20	80.23	67.0	99.3	9.66878
	5	8	82.8375	68.1	97.4	10.79854
	6	4	80.45	73.3	87.5	8.08393



Graph 1 – Values of $SvjO_2$ in group without ISC



Graph 2 – Values of $SvjO_2$ in group with ISC



Graph 3 – Values of $SvjO_2$ in both groups of patients in time-dependent manner

Discussion

The results of the measurements of oxygen saturation of mixed venous blood from the internal jugular vein ($SvjO_2$) in the group without intermittent sequential compression of the legs contribute to the hypothesis that the creation of pneumoperitoneum during laparoscopic surgery causes a decrease in cerebral oxygen saturation. In our study, the average baseline values of $SvjO_2$ in this group was 85.5%, while in the second measurement, after the creation of the pneumoperitoneum, the value of $SvjO_2$ decreased to average values of 77.8%, which is 9% less than the baseline value. The third measurement showed a 5.8% decrease in the average value of $SvjO_2$ compared to baseline values. Although further measurements show a tendency of recovery (85.5 → 77.8 → 80.6 → 83.8 → 84.8), the values of $SvjO_2$ remain lower than the baseline values for the entire duration of the surgery. Even after the termination of the pneumoperitoneum the average value of $SvjO_2$ was 1.3% lower than the baseline value, indicating that full recovery was not accomplished. This is in accordance with the findings of Kitajima et al. [21], Gipson et al. [22] and Kurukahvecioglu et al. [23], whose results also show a decrease in cerebral oxygen saturation after the creation of the pneumoperitoneum that persisted throughout the entire laparoscopy.

The results of the measurements of $SvjO_2$ in the group where ISC was applied are different compared to the values of $SvjO_2$ in the group without ISC (Table 1, Graph 2, Graph 3). In the second measurement, after the creation of the pneumoperitoneum, there was an increase in the average value of $SvjO_2$ of 4.8% compared to the baseline value, while in the group without ISC, there was a 9% decrease in the value of $SvjO_2$ compared to the baseline value in the same measurement. In the third measurement, the average value of $SvjO_2$ in the group with ISC was increased by 3.6% compared to baseline value, while in the group without ISC, the value of $SvjO_2$ was decreased by 5.8% compared to the baseline value. The application of ISC of the legs in our study resulted in an improvement of the oxygen saturation of the brain, especially in the period immediately after the creation of the pneumoperitoneum, which showed to be the most vulnerable phase for the patients, whereas despite the mechanisms of auto-regulation of the circulation of the brain, changes in the intra-abdominal and intra-cranial pressures caused a decrease in brain oxygenation. This is in accordance with the results of Kurukahvecioglu et al. (23), whose results also show that the changes in cerebral oxygen saturation can easily be restored by using intermittent sequential compression on the lower extremities.

It should be noted that the patients in this study belonged to groups 1 and 2 according to ASA classification, meaning that they had well-preserved mechanisms of auto-regulation of the brain circulation. Despite that, there was a decrease in the oxygenation of the brain in the group without ISC. A greater

decrease of the oxygenation of the brain should be expected in patients subjected to laparoscopic surgery who have concomitant diseases, especially cardio-circulatory, cerebrovascular or increased intra-cranial pressure, and they are the ones who should gain the greatest benefit from the use of ISC during laparoscopy. Further studies should be conducted that would include these populations of patients.

Conclusion

Application of intermittent sequential compression of the legs is a simple and safe technique for preserving brain oxygenation during laparoscopy by restoring the blood return from the legs.

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Резиме

ПОДОБРУВАЊЕ НА ОКСИГЕНАЦИЈАТА НА МОЗОКОТ ВО ТЕК НА ЛАПАРОСКОПИЈА СО УПОТРЕБА НА ИНТЕРМИТЕНТНА СЕКВЕНЦИОНИРАНА КОМПРЕСИЈА НА НОЗЕТЕ

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Создавањето на пневмоперитонеум од јаглероден диоксид во текот на лапароскопијата предизвикува низа несакани ефекти во организмот. Зголемениот интраабдоминален притисок, апсорбираниот јаглероден диоксид и зголемениот интракранијален притисок во текот на лапароскопијата предизвикуваат влошување на сатурацијата со кислород на мозокот.

Целта на оваа студија е да се испитаат можните ефекти на пневматската интермитентна секвенционирана компресија на нозете (ИСК) врз оксигенацијата на мозокот во текот на лапароскопијата.

Во оваа студија беа вклучени 100 пациенти подложени на елективна лапароскопска холецистектомија, кои според АСА класификацијата припаѓаат на групите 1 и 2. Пациентите беа поделени во две групи од по 50 пациенти, контролна група 1 и група 2, каде што беше аплицирана интермитентната секвенционирана компресија. Кислородната сатурација на мешаната венска крв од внатрешната југуларна вена ($SjvO_2$) е индиректен показател на потрошувачката на кислород во мозокот (оксигенација на мозокот). Примероците од крв беа земани од булбусот на десната внатрешна југуларна вена, бидејќи десната е доминантна дренажна страна на венската крв од мозокот. По добиената согласност од секој пациент, примероци од по 2 мл крв беа земани по неколку пати во текот на операцијата; првиот примерок непосредно по воведот во анестезија, со цел да се утврдат базичните вредности на $SjvO_2$, вториот примерок непосредно по создавањето на пневмоперитонеумот, и потоа на секои 15 минути до крајот на лапароскопијата. Последниот примерок беше земен пред екстубацијата на пациентите. Интермитентната компресија на нозете кај пациентите од втората група беше прекината по земањето на последниот примерок од крв.

Резултатите покажаа повисоки просечни вредности на кислородната сатурација на мешаната венска крв од внатрешната југуларна вена ($SjvO_2$) кај пациентите од групата 2, т.е. групата каде што беше аплицирана ИСК (82,3% → 86,4% → 85,3% → 80,2% → 82,8% → 80,4%), во споредба со групата 1, без ИСК (85,5% → 77,8% → 80,6% → 83,8% → 84,8%), со статистичка сигнификантност за $p < 0,05$ во второто и третото мерење, т.е. по создавањето на пневмоперитонеумот, кога влошувањето на оксигенацијата на мозокот е најизразено во групата без ИСК.

Апликацијата на интермитентната секвенционирана компресија на нозете во текот на лапароскопијата е едноставен и безбеден метод за зачувување на оксигенацијата на мозокот преку подобрување на венскиот повраток на крвта од нозете.

Клучни зборови: лапароскопија, оксигенација на мозокот, интермитентна секвенционирана компресија.

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