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Hemodynamics during laparoscopic extra- and intraperitoneal insufflation

An experimental study

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Abstract

Background: Total extraperitoneal laparoscopic surgery is an alternative to the laparoscopic transperitoneal route; however, its effects on hemodynamics have not been adequately studied. This experimental study compared the effects of intraperitoneal insufflation and extraperitoneal insufflation on hemodynamics and oxygen transport.

Methods: Sixteen pigs were randomly assigned for intraperitoneal insufflation or extraperitoneal insufflation with 15 mmHg carbon dioxide. Hemodynamic and oxygen transport parameters were taken during an hour of insufflation and analyzed for statistical differences.

Results: During extraperitoneal CO₂ pneumoperitoneum central venous filling pressures (central venous pressure, pulmonary capillary wedge pressure and mean pulmonary arterial pressure) and end-tidal CO₂ increased slower but to a similar magnitude in comparison to intraperitoneal insufflation. Cardiac output and indices of oxygen consumption and oxygen delivery were equally affected by both types of insufflation. Arterial CO₂ pressure increased significantly more during intraperitoneal insufflation.

Conclusion: The data from this study suggest that extraperitoneal insufflation might result in less cardiovascular impairment than intraperitoneal insufflation.

Key words: Laparoscopic surgery — Pneumoperitoneum — Hemodynamics — Extraperitoneal — Intraperitoneal

Laparoscopic procedures on extraperitoneally located anatomical structures—such as nephrectomy, adrenalectomy, lumbar sympathectomy, para-aortic lymph node sampling,

inguinal hernia repair, and bladder neck colposuspension—have been introduced into the surgical spectrum for clinical use [1–5, 10, 12]. The directness of the extraperitoneal approach and contraindications for transperitoneal endoscopic surgery—such as obesity, inadequate bowel preparation, and intraperitoneal adhesions—are factors that might make the extraperitoneal approach more attractive. This type of laparoscopic surgery may, however, be technically more demanding than its transperitoneal counterpart because of the limited view, the restricted working space, and the absence of familiar landmarks. This might result in prolonged procedures affecting the circulatory basis of the patient.

Pneumoperitoneum for laparoscopic surgery has been associated with hemodynamic changes. Clinical studies during intraperitoneal insufflation with carbon dioxide showed that arterial blood pressure increases and cardiac output decreases [8, 13]. Few data exist on the hemodynamic effects of laparoscopy in an extraperitoneally created cavity. If an extraperitoneal laparoscopic procedure results in more circulatory depression, its potential usefulness in humans would be limited. In this experimental study we compared the effects of extraperitoneal and intraperitoneal laparoscopic insufflation on the hemodynamic parameters in a porcine model.

Materials and methods

Sixteen pigs (27–35 kg) were used in this study. Anesthesia was induced with an i.m. injection of azaperon (12 mg/kg) and atropine (1 mg). After endotracheal intubation the lungs of the animals were mechanically ventilated at a rate of 12 breaths/min with a tidal volume of 10 ml/kg, with a mixture of oxygen in air (FIO₂ = 0.4). Anesthesia was maintained with 0.7–1.0% halothane (inspired concentration) and the infusion regimen consisted of lactated Ringer's solution at a rate of 4 ml/kg/h during the experiment. The right internal jugular vein was exposed and a flow-directed pulmonary arterial catheter (Baxter, Americ Edwards Laboratories, Irvine, CA, U.S.A.) was inserted and floated into the pulmonary artery. A Wallace 16-gauge catheter was placed in the right brachial artery for arterial pressure measurements and arterial blood-gas sampling.

Fig. 1. Hemodynamic variables during extraperitoneal (—□—) and intraperitoneal (—○—) carbon dioxide insufflation. Each data point represents the mean $\pm$ SD ($n = 8$).

On a random basis eight pigs were assigned to extraperitoneal insufflation and eight to intraperitoneal insufflation with carbon dioxide. Through a modified open Hasson technique, as described by Horattas [7], a disposable 10-mm trocar was placed, extraperitoneally or intraperitoneally, and connected to a pressure-controlled carbon dioxide insufflator (Electronic Laparoflator 263400-20, Storz-Endoskop, Switzerland) set at 15 mmHg pressure.

We attempted to create an extraperitoneal cavity of approximately 1 l of CO_2 gas. From previous animal experiments we noted that this volume is sufficient to create a cavity large enough to be able to perform endoscopic retroperitoneal nephrectomy, para-aortic lymph-node sampling, or lumbar sympathectomy [1–3]. On average, the amount of gas necessary to create a 15-mmHg intraabdominal pressure in these animals was 5 l CO_2 .

Hemodynamic measurements were recorded using disposable transducers (Gould, U.S.A.). Measurements were made for cardiac output (mean of four determinations by thermodilution, using room-temperature normal saline injectate (5 ml), Edwards Laboratories, Santa Ana, CA, U.S.A.), heart rate, mean arterial blood pressure, central venous pressure, mean pulmonary arterial pressure, pulmonary capillary wedge pressure, and end-tidal carbon dioxide. Arterial and central venous blood samples were taken for gas analyses of arterial oxygen, arterial carbon dioxide pressure, and mixed venous oxygen saturation (ABL II, Radiometer, Copenhagen, Denmark).

After preoperative workup the pigs were positioned in the supine position and allowed a stabilization period of 20 min before control measurements were taken. After starting the insufflation, measurements were made as follows; 1 min after insufflation with carbon dioxide, 5 min, 10 min, 15 min, 30 min, 45 min, and 60 min after insufflation. After the last sample was taken the pneumoperitoneum was desufflated and a control sample was taken after 10 min of desufflation. Blood samples were drawn during each measurement.

Results are expressed as mean $\pm$ SD. Data was analyzed with two-way analysis of variance for repeated measures. When indicated, differences between means were analysed using paired *t*-tests with Bonferroni correction for multiple comparisons. Blood-gas measurements were analyzed with the Mann-Whitney U test; *p* values of <0.05 were considered statistically significant.

Results

Hemodynamic changes with both insufflation methods are shown in Fig. 1. Heart rate did not change significantly during either of the insufflation methods. Although mean arterial blood pressure and cardiac output did increase significantly during intraperitoneal insufflation, but not during extraperitoneal insufflation, the differences between both methods were not significant.

Filling pressures such as central venous pressure, mean

pulmonary arterial pressure, and pulmonary capillary wedge pressure increased significantly during the first minutes of intraperitoneal insufflation, reaching a plateau after approximately 10 min. These pressures showed a more gradual increase during extraperitoneal insufflation, reaching a plateau after 45 min. Differences in this respect were significant between both methods.

The gas exchange parameters are shown in Fig. 2. There is a rapid increase of end-tidal CO_2 during the first few minutes of intraperitoneal insufflation, reaching a plateau after 10 min. End-tidal CO_2 during extraperitoneal insufflation increases at a slower pace and the magnitude of the increase is significantly lower than with intraperitoneal insufflation.

During both insufflation methods arterial CO_2 pressure increases, but the increase during intraperitoneal insufflation is significantly larger in magnitude than with extraperitoneal insufflation. pH decreased similarly in both groups. The arterial oxygen pressure and central venous oxygen saturation did not change significantly during either of the insufflation procedures.

Discussion

Extraperitoneal laparoscopic surgery is rapidly becoming an established route for surgical procedures. The effects of extraperitoneal insufflated carbon dioxide on gas exchange have been studied previously; however, the effects on hemodynamics are not yet clear. Our data concerning hemodynamic changes suggests that extraperitoneal insufflation with carbon dioxide is associated with hemodynamics similar to those observed during intraperitoneal insufflation. Extraperitoneal insufflation is associated with less rapid increases in central venous filling pressures compared to intraperitoneal insufflation.

The mechanisms that are responsible for the hemodynamic changes during laparoscopic surgery appear to be multifactorial. Both pressure and pharmacological effects of the insufflated gas may affect hemodynamics. Pressure gradients will affect venous return. Increases in venous return secondary to increased intraperitoneal pressure have been reported to augment cardiac output. In general, however,

Fig. 2. Gas exchange variables during extraperitoneal (—□—) and intraperitoneal (—○—) carbon dioxide insufflation. Each data point represents the mean $\pm$ SD ($n = 8$).

venous return is expected to decrease during intraperitoneal insufflation, as indicated by decreases in cardiac performance. This apparent contradiction may be explained by a time-dependent phenomenon. Initially, blood will be squeezed out of the abdominal cavity to the heart, causing a transient increase in cardiac output. Secondly, sustained increases in intraabdominal pressure will ultimately impede venous return and depress cardiac output. In addition to the pressure effects, pharmacological effects of the insufflation gas will affect hemodynamics during laparoscopy. The absorption of CO₂ from the insufflation cavity, resulting in mild hypercarbia, is associated with sympathetic stimulation, which may increase heart rate, blood pressure, systemic vascular resistance, and cardiac output. On the other hand, severe acidemia and hypercapnia may depress heart performance, secondary to decreases in myocardial inotropy.

We did observe significant increases in cardiac output and blood pressure during intraperitoneal insufflation, but not during extraperitoneal insufflation. Heart rate did not increase with either method. A clinical study [15] recently confirmed this data. However, in this nonrandomized study, measurements were only taken just before and at the end of the insufflation period. Furthermore, cardiac output and central venous filling pressures were not measured. Our results concerning cardiac output are in contrast to most human studies, which report moderate decreases in cardiac output during intraperitoneal insufflation. Studies performed in pigs may give different hemodynamic results compared to studies in humans. There are no data on human studies measuring cardiac output and central filling pressures during extraperitoneal laparoscopy. We could not demonstrate a significant difference between the extra- and the intraperitoneal approach with respect to cardiac output, blood pressure, and heart rate. Indeed, central venous oxygen saturation, which reflects global oxygen delivery to the tissues, was not affected by either approach. Therefore, it seems reasonable to assume that cardiac performance is affected similarly by both the extra- and the intraperitoneal approach.

Central venous filling pressures increased during both intra- and extraperitoneal insufflation. However, during intraperitoneal insufflation, central filling pressures increased

faster than during extraperitoneal insufflation. Maximum pressures were reached on average 30 min earlier during the intraperitoneal approach. A possible explanation for this phenomenon might be that pressures are transmitted more quickly into the thorax during intraperitoneal insufflation. The soft tissues that cover the extraperitoneal cavity may serve as a buffer and may therefore delay the transmission of the pressure into the thorax. In theory, this might be advantageous for patients with limited cardiac reserve. However, whether the differences between both methods with respect to the central venous filling pressures are of any clinical consequence remains to be determined. The duration of an extraperitoneal approach is on average longer than 45 min. Therefore, it is to be expected that during an extraperitoneal procedure central venous filling pressures are elevated throughout a significant part of the procedure.

Gas-exchange parameters showed an earlier and stronger tendency toward the development of respiratory acidosis in the intraperitoneal insufflation group. These findings are in agreement with others that showed, in an experimental study in dogs, that if the insufflated gas is limited to the retroperitoneal space, the absorption of CO₂ appears to be reduced compared to intraperitoneal insufflation [14]. These findings contrast with a study that showed more marked CO₂ diffusion into the body during extraperitoneal than during intraperitoneal CO₂ insufflation [11]. However, in that study three different operations were evaluated, which might have influenced the results. Two mechanisms contribute to the development of hypercarbia during laparoscopy: absorption from the intra- or extraperitoneal cavity and increased physiologic dead space ventilation. Lister showed in an experimental study on pigs that CO₂ absorption from the abdominal cavity depends on the level of intraabdominal pressure [9]. He hypothesized that by increasing the intraabdominal pressure from 0 to 10 mmHg a progressively larger area of the peritoneum is exposed to CO₂, resulting in an increase in the diffusion area. Increasing intraperitoneal insufflation pressures above 10 mmHg will not result in any further increase in the diffusion area, causing a plateau in CO₂ absorption. Nevertheless, a further increase in arterial CO₂ pressure may occur as a result of increases in physiologic dead space ventilation. The greater absorptive capacity of the peritoneal membrane may also be reflected in a

greater systemic absorption of CO₂ [6]. Our results indicate that the extraperitoneal insufflation is associated with lower arterial CO₂ pressure values compared to intraperitoneal insufflation. A possible explanation might be that during extraperitoneal insufflation a relatively small cavity was created, resulting in a small diffusion area for CO₂.

A possible criticism of the study protocol is that the two different experiments were not compared in the same animal. Performing both intra- and extraperitoneal measurements in the same pig would only be feasible in the half of the animals where the intraperitoneal experiment was carried out first. The opposite order of experiments is, however, impossible. The creation of an extraperitoneal area causes the peritoneum to detach from the fascia of the abdominal muscles. This would have biased the intraperitoneal measurements. For this reason the randomized model was selected in which to perform the comparative measurements.

In conclusion, our results indicate that extraperitoneal insufflation with CO₂ for laparoscopy is associated with hemodynamic changes similar to those observed during intraperitoneal insufflation. Intraperitoneal insufflation is associated with more rapid changes in central venous filling pressures. Gas-exchange variables indicate a stronger tendency toward the development of respiratory acidosis during conventional intraperitoneal insufflation.

The data from this study suggests that extraperitoneal insufflation might result in less cardiovascular impairment than intraperitoneal insufflation.

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