Comparative Study of the Changes in Partial Pressure of Plasma Carbon Dioxide During Carbon Dioxide Insufflation into the Intraperitoneal and Preperitoneal Spaces

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Abstract

Background: We aimed to compare plasma concentrations of carbon dioxide (CO$_2$) in dogs that underwent intra- and preperitoneal CO$_2$ insufflation.

Materials and Methods: Thirty dogs were studied. Ten formed a control group, 10 underwent intraperitoneal CO$_2$ insufflation, and 10 underwent preperitoneal CO$_2$ insufflation. General anesthesia with controlled ventilation was standardized for all dogs. After stabilizing the anesthesia, blood samples were collected at predetermined times and were sent for immediate gasometric analysis. Analysis of variance was used for comparing variables.

Results: The plasma CO$_2$ concentration in the intraperitoneal insufflation group increased significantly more than in the preperitoneal insufflation group and was significantly greater than in the control group (P < 0.05). The pH values in the intraperitoneal group were lower than in the preperitoneal group (P < 0.05).

Conclusion: The data from this study suggest that a greater plasma concentration of CO$_2$ is achieved by insufflation at constant pressure into the intraperitoneal space than into the preperitoneal space.

Introduction

The use of carbon dioxide (CO$_2$) to optimize the operating space during videosurgical procedures causes an increase in the plasma concentration of CO$_2$. With the advances in videosurgical techniques and the development of this tool, the possibility of using the preperitoneal space as an option for gaining surgical access to organs located in the extraperitoneal space has been created. Examples of videosurgical procedures with the possibility of a preperitoneal approach would include herniorrhaphy, nephrectomy, adrenalectomy, sympathectomy, prostatectomy, and lymphadenectomy.

There is controversy in the literature regarding whether, during insufflation of CO$_2$ dioxide into the preperitoneal space, there is higher,1–6 lower,7,8 or the same9 plasma concentration of this gas, in comparison with intraperitoneal insufflation. In this experimental study, we evaluated and compared the changes in partial pressure of CO$_2$ in the bloodstream of dogs during insufflation of CO$_2$ into the intra- and preperitoneal spaces. This study was approved by the Research Ethics Committee of Heliópolis Hospital (São Paulo, Brazil).

Materials and Methods

Thirty mongrels were used in this study. They were randomly divided into three groups, such that the dogs were allocated to each group by means of a draw. The groups were a control group (n = 10), a group with intraperitoneal insufflation of CO$_2$ (n = 10), and a group with preperitoneal insufflation of CO$_2$ (n = 10). The animals’ weights ranged from 10 to 22 kg, and there were no significant differences between the study groups. Dogs that were not clinically healthy and those with blood hemoglobin levels less than 10 g/dL were excluded from the study.

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Anesthesia was induced by means of an intramuscular injection of promazine (0.1 mg/kg), complemented with sodium thiopental (20 mg/kg), and using pancuronium bromide (0.08 mg/kg) as a muscle relaxant. After orotracheal intubation, the animals were kept on mechanical ventilation, with a frequency of 30 respiratory incursions per minute and a current volume of 15 mL/kg. The anesthesia was maintained by using isoflurane, with a mean arterial pressure of 80 mm Hg. Physiologic solution (10 mL/kg/h) was infused intravenously throughout the procedure into the peripheral veins. The right femoral artery was dissected and repaired in order to collect gasometric samples. The left femoral artery was catheterized, and a system was introduced for monitoring the mean invasive arterial pressure, measured by using isoflurane, with a mean arterial pressure of 12 mm Hg.

After stabilizing the anesthesia, the first blood sample was collected. Next, CO₂ insufflation was started, except in the control group. Blood samples were collected every 15 minutes until 75 minutes of the experiment had been completed from all groups. For the groups that received insufflation, the CO₂ was withdrawn after making the collection at the 60th minute. For the group with preperitoneal insufflation, after the 75th minute, a new insufflation of the preperitoneal space was performed. A median laparotomy was then performed on the animal. The absence of macroscopic perforation of the peritoneum was confirmed when it was observed that there was no air escape during the laparotomy procedure; there was bulging of the whole parietal peritoneum, and there was no bubbling after irrigation of the peritoneal cavity, using physiologic solution.

To analyze the results, the statistical test of analysis of variance (ANOVA) for nonindependent groups was applied, with the aim of comparing the values obtained over the study period. One-way ANOVA was used to compare the variables at each data collection time of the study in the three groups analyzed. The rejection level for the nullity hypothesis was set at 0.05 or 5%.

Results

Changes in the plasma concentration of carbon dioxide (pCO₂) in the arterial blood were observed over the analysis period (Table 1). At the starting time (T0), there was no significant difference (P < 0.05) in pCO₂ between the control group (C), preperitoneal insufflation group (PP), and intraperitoneal insufflation group (IP). At the times of 15, 30, 45, and 60 minutes (T15, T30, T45, and T60), it was observed that the increase in pCO₂ was greater in IP than in PP (P < 0.05). At the time of 75 minutes (T75), following 15 minutes of desufflation of CO₂, there was no statistically significant difference between the groups (P < 0.05).

From the analysis of the different times in each group, it was observed that the group with intraperitoneal insufflation had pCO₂ values greater than at the starting time (T0) and at the times T15, T30, T45, T60, and T75 (P < 0.05), while the group with preperitoneal insufflation had pCO₂ values greater than at the starting time (T0) and at the times T30, T45, T60, and T75 (P < 0.05). The changes in plasma pH values are shown in Table 2. The pH value at the times of 15, 30, 45, 60, and 75 minutes (T15, T30, T45, T60, and T75) were observed to be lower in IP than in PP (P < 0.05). With regard to plasma bicarbonate, partial pressure of arterial oxygen, and oxygen saturation, the differences between the groups at the times studied were nonsignificant.

Discussion

Videosurgery is becoming the method of choice for surgically treating a wide variety of diseases because of the benefits of minimally invasive surgery. The space to be probed when using this technique, for example, the peritoneal space, needs to be transformed into a real space, thereby obtaining an area that can be viewed better and presenting adequate exposure. To create this space, gas insufflation is generally used. Today, the gas most used is CO₂ because of its low cost, noninflammability, and known metabolism in the human organism. CO₂ is usually produced in physiologic organic reactions and is eliminated in the air by being exhaled from the lungs.

With CO₂ insufflation in laparoscopic procedures, alterations in the acid-alkaline balance take place due to absorption of this gas by the peritoneal serosa and the increased intra-abdominal pressure. This causes respiratory acidosis, which is usually kept under control by the anesthesiologist by means of controlling the respiratory parameters and administering drugs. In situations in which the patient already has an underlying disease, such as cardiopathy or pneumopathy, such changes are potentially dangerous. Hypercarbia, which is associated with acidosis, may cause cardiac arrhythmia of varying intensity, and this is particularly of concern among patients with previous cardiopathy. Patients with chronic obstructive pulmonary disease may present with increased concentrations of plasma CO₂ because of difficulty in achieving gas exchange in the lungs when undergoing CO₂ insufflation for videodendoscopic procedures. They may, therefore, present situations of significant hypercarbia, with its deleterious consequences. The intraperitoneal CO₂ causes cardiovascular changes during the pneumoperitoneum because of mechanical factors relating to intra-abdominal pressure growth. These changes affect the ventilation and venous return, as well as the CO₂ absorption into the circulation. Such events explain the acidosis and, consequently, the cardiovascular depression. However, with preperitoneal insufflation, these effects are minimized and there is a decrease in plasma CO₂ concentration plasma CO₂, as shown through our results.
### Table 1. Dogs in the Groups with Intra- and Preperitoneal Carbon Dioxide Insufflation and in the Control Group

<table>
<thead>
<tr>
<th></th>
<th>Intrapерitoneal</th>
<th>Preperitoneal</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T0</td>
<td>T15</td>
<td>T30</td>
</tr>
<tr>
<td>mean</td>
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<td></td>
</tr>
<tr>
<td>time</td>
<td></td>
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<tr>
<td></td>
<td>53.5</td>
<td>68.6</td>
<td>36.2</td>
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<tr>
<td>SD</td>
<td>11.58</td>
<td>29.21</td>
<td>28.43</td>
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*aAccording to partial pressure of carbon dioxide at the times studied.

### Table 2. Dogs in the Groups with Intra- and Preperitoneal Carbon Dioxide Insufflation and in the Control Group

<table>
<thead>
<tr>
<th></th>
<th>Intrapерitoneal</th>
<th>Preperitoneal</th>
<th>Control group</th>
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<tr>
<td></td>
<td>T0</td>
<td>T15</td>
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<tr>
<td>mean</td>
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<td>time</td>
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<td></td>
<td>7.209</td>
<td>7.103</td>
<td>7.290</td>
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<tr>
<td>SD</td>
<td>0.002</td>
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*aAccording to pH, at the times studied.
In our study, the groups analyzed underwent arterial gas measurements at different study times, with the aim of observing the behavior of the gasometric variables in relation to the anesthesia, pneumoperitoneum, and pneumoperitoneal insufflation. Our study demonstrated that there was a greater plasma concentration of CO\(_2\) in the group with insufflation of this gas into the intraperitoneal space, in comparison with the preperitoneal insufflation group and the control group (Table 2).

Under conditions of a pneumoperitoneum with CO\(_2\), this gas is absorbed by the peritoneum and causes hypercarbia.\(^9\) The absorption is related to the contact area, which is generally greater in the intraperitoneal area. However, there may be a dissection of preperitoneal layers by the insufflated gas, thereby creating a large contact area. Another reason for the rise in partial pressure of CO\(_2\) during the pneumoperitoneum would be the increase in intra-abdominal pressure, which would alter the pulmonary ventilation-perfusion ratio by raising the phrenic cupolas.\(^11\) With insufflation of the abdominal cavity, compression of the diaphragm occurs, and through this, the pulmonary compliance decreases and the dead space increases, thus making gas exchange difficult.

Our results are in agreement with those of Wolf et al., who also found greater CO\(_2\) absorption from intraperitoneal than from preperitoneal insufflation.\(^7\) One critical factor in their study was the small number of animals in the experiment (only 2 dogs with preperitoneal insufflation) and another was the lack of a control group for data comparison. These points make it difficult to extrapolate the data from their experiment to clinical situations. To avoid such bias, we incorporated a control group without insufflation and had three groups with equal numbers of animals. We consider that this control group was important, because we believe that, despite using the same anesthesia standard for all the procedures, gasometric changes consequent to the anesthesia could have occurred, which would have invalidated our results. In our study, the pCO\(_2\) in the control group at the end of the procedure was found to be slightly higher than at the starting time (T0), but without reaching statistical significance.

Bannenberg et al. carried out a study on pigs and also found a greater increase in arterial CO\(_2\) pressure from intraperitoneal than from preperitoneal insufflation, thereby agreeing with our findings.\(^8\) On the other hand, Wright et al. found similar magnitudes of increases in partial pressure of CO\(_2\) during procedures with preperitoneal or intraperitoneal insufflation.\(^9\)

Mullet et al., Liem et al., Sumpf et al., Streich et al., Demirouk et al., and Meininger et al. all carried out clinical studies on humans and concluded that there was lower CO\(_2\) absorption when using the intraperitoneal insufflation technique than there was with preperitoneal insufflation, which was contrary to our results.\(^1-6\) We must emphasize that difficulties exist in interpreting data from a human experimental model, considering that once gasometric changes are detected, it becomes mandatory to make corrections to the anesthesia parameters, which may invalidate the results. In our study, the preestablished anesthesia parameters were conserved, in spite of the elevation of pCO\(_2\) and consequent acidosis, with decreasing plasma pH.

We believe that the volume of gas insufflated into the preperitoneal space, that is needed for maintaining a constant insufflation pressure, depends on the compliance of this space. This is related to the initial dissection performed before placing the trocar and to the dissection produced by the gas insufflation pressure. To maintain a pressure of 12 mm Hg in the peritoneal cavity of our dogs, 2–3 L of CO\(_2\) were needed, while to maintain the same pressure in the preperitoneal space, 1–2 L of CO\(_2\) were needed. However, in the preperitoneal group, a gradual expansion of the space was observed, which was demonstrated by the additional insufflation to 2–3 L in order to maintain the same pressure of 12 mm Hg. Therefore, although initially the volume of CO\(_2\) insufflated into the intraperitoneal space may be smaller than what is used in the preperitoneal space, there is a tendency with prolonged procedures for the volume insufflated into the preperitoneal space to increase. This is due to dissection of preperitoneal layers by the gas, and there may be a greater concentration of plasma CO\(_2\) in these cases. The preperitoneal space does not have well-defined anatomic limits, and thus, additional dissection of this space does not have well-defined anatomic limits. Therefore, additional dissection of the space is dependent on the inflation pressure level and, consequently, the volume used to maintain the space. It is possible that, for prolonged management involving high levels of CO\(_2\) to maintain the space, evolution with increasing plasma CO\(_2\) pressure may occur. Our experience from evaluating 60 minutes of inflation, with a well-established inflation of 12 mm Hg, showed that a progressive increase in pCO\(_2\) occurred in the preperitoneal inflation group, even though the level was statistically lower than in the intraperitoneal group.

Another factor that may explain findings that differed from ours might be perforation of the peritoneum with undetected leakage of CO\(_2\) from the preperitoneal space to the intraperitoneal space. Most of these other researchers did not comment on the possibility of perforation of the peritoneum, which might have allowed gas insufflated into the preperitoneal space gas to enter the intraperitoneal space. In our study, we took the precaution at the end of the experiment to carry out a laparotomy on the group with preperitoneal insufflation in order to confirm the integrity of the peritoneum and absence of leakage of gas into the intraperitoneal space. It is likely that, during insufflation of the retroperitoneum, even without evident perforation of the peritoneum, some passage of CO\(_2\) may occur into the peritoneal cavity. However, this was not demonstrated macroscopically in our experiment.

Although other options exist, insufflation with CO\(_2\) is currently the method of choice in most services performing videoendoscopic surgery. One of the ways that we believe might minimize the deleterious effects of CO\(_2\) would be to insufflate this gas into locations that give rise to lower absorption, thereby maintaining good conditions for the endoscopic surgical approach. In accordance with our results, for procedures in which there is the choice of performing either intra- or preperitoneal insufflation, preference should be given to using a preperitoneal approach. It can, therefore, be inferred that the preperitoneal route is safer from the point of view of increased CO\(_2\) concentration.

Corroborating our preference, there are other studies that demonstrate that a pneumoperitoneum causes greater systemic and renal hemodynamic changes than does a pneumoretropneumoperitoneum.\(^12\) Recent studies in the litera-
ture have described the possibility of using a preperitoneal endoscopic approach for inguinal herniorrhaphy without general anesthesia, with the options of spinal or local anesthesia.

Our results agree with these researchers views that preperitoneal procedures can be performed without the need for general anesthesia, considering that the modifications to the acidic and basic balance, through CO$_2$ retention, are less important than when using an intraperitoneal access. The urologic system is another area in which the preperitoneal route can be used for a set of procedures: Nephrectomy, prostatectomy, and lithotomy are routinely performed by using a preperitoneal endoscopic route.

**Conclusion**

In conclusion, we recommend that, when possible, preperitoneal access should be the first-choice route. This avoids the mechanic effects of increased intraperitoneal pressure, followed by changes in acidic and basic balance, since there is greater plasma concentration of CO$_2$ when insufflated at constant pressure into the intraperitoneal space than when insufflated into the preperitoneal space.

**Disclosure Statement**

No competing financial interests exist.

**References**


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