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The effect of experimentally induced carbon dioxide pneumoperitoneum on intra-abdominal and intra-esophageal pH

Aim: An experimental study was performed to evaluate the effect of CO_2 pneumoperitoneum on intra-abdominal (IA) and intra-esophageal (IE) pH.

Material and methods: The study included 18 Wistar rats. In the control group (n = 6) a pH catheter was inserted into the peritoneal cavity via a left upper quadrant incision and another catheter was inserted into the lower esophagus via the oral route. Pre- and post-insufflation IA and IE pH were recorded every 5 min for 1 h. In the experimental groups, in addition to pH catheters, a 16-G catheter was inserted into the abdomen above the umbilicus. In the O_2 group (n = 6) 95% O_2 and 5% CO_2 were insufflated with a pressure of 10 mmHg. In the CO_2 group (n = 6), CO_2 was insufflated with the same pressure and duration.

Results: In the CO_2 group, IA and IE pH values significantly decreased ($P < 0.05$). IA pH values decreased in the CO_2 group when compared to the control and O_2 groups ($P < 0.05$). There was not a significant difference in IE pH between the CO_2 group and the other groups.

Conclusion: CO_2 insufflation decreased IA pH values. Decreased pH values obtained with continuous recordings of the esophagus may have been related to increases in intra-abdominal pressure, rather than the metabolic effects of CO_2 pneumoperitoneum.

Key words: Carbon dioxide, pH, pneumoperitoneum, esophagus, abdomen

Deneysel karbondioksit pnömoperitonyumunun intra-abdominal ve intra-özofageal pH'ya etkisi

Amaç: Karbondioksit ile elde edilen pnömoperitoneumunun intra-abdominal (IA) ve intraözofageal (IÖ) pH'ya etkisini değerlendirmek amacıyla deneysel bir çalışma yapılmıştır.

Yöntem ve gereçler: Çalışmaya 18 adet Wistar rat dahil edilmiştir. Kontrol grubunda (n = 6), peritoneal kaviteye sol üst kadrandan yapılan kesiden pH kateteri yerleştirilmiş ve bir başka katater ise ağız yoluyla özofagus alt ucuna yerleştirilmiştir. İnsüflasyon öncesi ve sonrası IA ve IÖ pH (MMS Synetics, Hollanda) kayıtları 5 dakika aralıklarla bir saat boyunca elde edilmiştir. Deney gruplarında pH kataterlerine ek olarak, 16 G katater göbek üstünden abdomene yerleştirilmiş ve 10 mmHg basınçla, % 95'lik O_2 ve % 5'lik CO_2 insufle edilerek ile O_2 grubu (n = 6) oluşturulmuştur. CO_2 grubunda (n = 6) aynı basınç ve sürede CO_2 insüflasyonu yapılmıştır.

Bulgular: CO_2 grubunda pH değerleri IA ve IÖ ölçümlerde anlamlı olarak azalmıştır ($P < 0,05$). IA kayıtlarda, pH değerleri CO_2 grubunda kontrol grubu ve O_2 grubuyla karşılaştırıldığında belirgin azalmıştır ($P < 0,05$). IÖ kayıtlar bakımından CO_2 grubu ile diğer gruplar arasında fark bulunmamıştır.

Sonuç: CO_2 insuflasyonu IA pH'yı azalmaktadır. Tekrarlayan özefagus kayıtlarında elde edilen azalmış pH değerleri CO_2 pnömoperitoneumunun metabolik etkilerinden çok artan intra-abdominal basınca bağlı olabilir.

Anahtar sözcükler: Karbon dioksit, pH, pnömoperitoneum, özofagus, abdomen

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Introduction

Most minimally invasive procedures require a pneumoperitoneum to achieve good exposure and visualization (1). Due to its many advantages, CO_2 is the most commonly used gas for pneumoperitoneum (2); however, insufflated CO_2 is absorbed from the peritoneum into the bloodstream and can induce metabolic effects like acidosis and hypercapnia (2).

Although it is thought that laparoscopic procedures contribute to early recovery of gastrointestinal motility, several studies have demonstrated inhibited gastrointestinal smooth muscle activity in acidosis (2,3). Not only acidosis, but also decreased pH values of media may alter gastrointestinal motility (4); however, it has been reported that CO_2 insufflation significantly decreased peritoneal pH and that pH alterations in the esophagus have not been evaluated (5). We aimed to determine esophageal pH alterations and peritoneal pH changes under the influence of CO_2 insufflation. An experimental study was performed to evaluate the effect of CO_2 pneumoperitoneum on intra-abdominal (IA) and intra-esophageal (IE) pH.

Materials and methods

The study included 18 albino Wistar rats (male and female) weighing 200-250 g. Care and use of the animals in this study conformed to the recommendations of the Declaration of Helsinki, and internationally and locally accepted principles were taken into consideration. The study was approved by the local ethics committee.

Rats were randomly allocated into 3 groups: control, oxygen (O_2, sham group), and carbon dioxide (CO_2) groups. General anesthesia was induced with intramuscular ketamine hydrochloride (20 mg kg^{-1}, Ketalar, Parke-Davis) and xylazine (4 mg kg^{-1}, Rompun, Bayer, Germany).

pH monitoring

Intra-abdominal and IE pH measurements were performed with antimony catheters that were calibrated before the experiments with pH 7 and pH 1 buffer solutions (Synetics). The pH catheter was inserted into the abdomen via a mini incision from the left upper quadrant and another catheter was inserted into the lower esophagus via the oral route by measuring the length between the chin and xyphoid. The tip of the abdominal catheter was positioned so that it was always in contact with the peritoneal surface of the small bowel or its mesentery, as described by Neuhaus et al. (6). The position of the IE catheter was controlled after the experiments via median laparotomy. Concomitant pH recordings of the abdomen and esophagus were performed before and during insufflation every 5 min (pH recorder, MMS Synetics, Netherlands).

Experimental groups

In the control group (n = 6), after anesthesia IA and IE were recorded every 5 min for 1 h. In addition to a pH catheter a 16-G catheter was inserted into the abdomen above the umbilicus and insufflated with 95% O_2 or 5% CO_2 with 10 mmHg of pressure for 1 h in the oxygen or sham group. In the CO_2 group (n = 6), CO_2 was insufflated with the same pressure for 1 h to measure pH values. In all the experiments, a baseline pH recording was obtained before insufflation and pH values were recorded at 5-min intervals after insufflation.

Statistical analysis

Data obtained with a pH meter were analyzed with Graph Pad Prism v.3.0 software. The pH recordings obtained during the 1-h procedure in each group were compared by repeated measures of ANOVA. The IA and IE pH values in the CO_2 group were compared with those in the O_2 and control groups by nonparametric Kruskal Wallis ANOVA; P values < 0.05 were considered to be significant.

Results

All of the rats completed the experiment and 1-h insufflation with a pressure of 10 mmHg was tolerated by the animals. The pH-time graphs of the IA and IE recordings in the 3 groups are shown in Figures 1 and 2, respectively. The repeated IA and IE pH recordings were compared in each group and between the 3 groups.

Comparison of repeated pH values in each group

When we evaluated the repeated pH values in each group, IA pH did not show any difference in the control group, while it decreased significantly in the

CO_2 and O_2 groups during the experiment ($P < 0.01$) (Figure 1). Although the recorded IE pH values in the O_2 group did not change, they significantly decreased in the CO_2 and control groups (***$P < 0.0001$ and *$P < 0.01$ respectively) (Figure 2).

Comparison of the 3 groups

A comparison of the IA recordings in the CO_2 group with those in the control and O_2 groups shows that CO_2 insufflation for 1 h lowered abdominal pH more in the CO2 group in than the others (*$P < 0.05$ and **$P < 0.01$, Figure 1); however, no difference was observed in the IE recordings between the 3 groups (Figure 2).

Discussion

Minimally invasive surgery has gained clinical acceptance in recent years for the treatment of children with a variety of diseases (7). There is widespread agreement that laparoscopic surgery reduces overall morbidity and mortality. Even though these procedures are associated with such advantages as early recovery, less pain, and less systemic immune depression, they have also been associated with new complications. The majority of these complications are related to the use of CO_2 as an insufflation gas (6).

CO_2 pneumoperitoneum causes hypercapnia and acidosis due to increased absorption of CO_2 by the peritoneum (8). CO_2 rapidly converts to carbonic acid in body fluids and alters local pH (5). Thus, CO_2 can reduce both systemic and local pH elsewhere in the body.

Extracellular acidosis may decrease the sensitivity of polarized smooth muscle membranes to contracting agonists and reduces the rate of Ca^{++} release into muscle cells (2). Many studies report that hypercapnia and acidosis may inhibit gastrointestinal smooth muscle activity (3,9). Waseda et al. reported that CO_2 pneumoperitoneum may diminish smooth muscle activity and delay recovery of gastrointestinal motility (2); however, Unsal et al. suggest that CO_2 pneumoperitoneum inhibits contractile responses in the rat ileum only at higher IA pressures and that esophageal contractility under the influence of CO_2 insufflation was not evaluated previously (10). We evaluated both IA and IE pH values for 1 h at a pressure of 10 mmHg to observe pH alterations in the esophagus.

Kuebler et al. reported that acidification associated with CO_2 pneumoperitoneum is limited to the area of inspection and manipulation (5). Moreover, they suggest that neither changes in pressure nor the insufflation rate has a major effect on peritoneal pH. Although, Kuntz et al. demonstrated that laparoscopic procedures lead to a significant reduction in blood and subcutaneous tissue pH during CO_2 insufflation, it has been proposed that abdominal insufflation with CO_2 can cause peritoneal acidosis independent of systemic pH alterations (1,11). Neuhaus et al. reported that intraperitoneal pH values may increase during continuous insufflation in humans due to positive pressure ventilation during surgery (6). In contrast, we achieved a progressive reduction in pH values in spontaneously breathing rats. We think that the

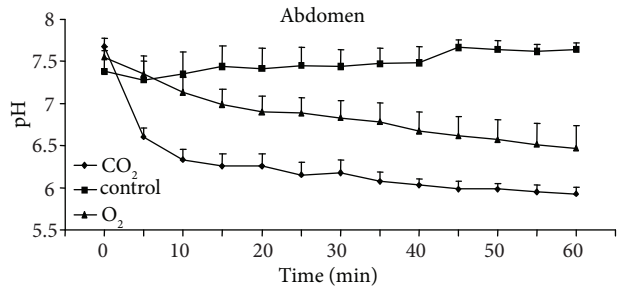

Figure 1. Intra-abdominal pH recordings in the control, CO_2, and O_2 groups (*$P < 0.05$ and **$P < 0.01$).

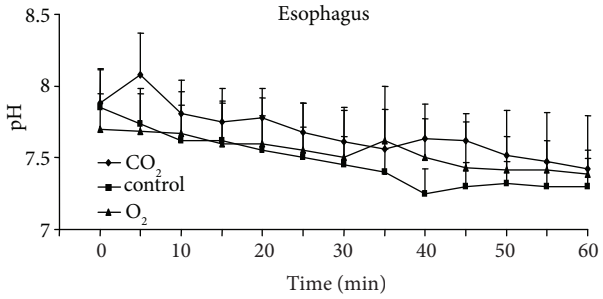

Figure 2. When intra-esophageal pH recordings in the control, CO_2, and O_2 groups were compared, there was not a significant difference between the 3 groups; however, pH values in the control (*$P < 0.01$) and CO_2 groups (***$P < 0.001$) decreased.

decrease in IA pH values may have been related to the direct detection of CO_2 from the antimony pH catheters.

It has been demonstrated that CO_2 pneumoperitoneum and hypercapnia have no effect on the lower esophageal sphincter (12). In our experiment, however, the esophagus was not exposed to CO_2 during insufflation; we observed a decrease in IE pH values in repeated recordings. IE pH values did not decrease as much as IA values. Almost all of the IE pH values in the CO_2 group were > 7.0, and they were not significantly different than those in the control and O_2 groups. According to our findings, we suggest that decreased pH values in IE recordings may have been related to increased IA pressure. In experimental models increased IA pressure may have led to gastroesophageal reflux episodes because the gastroesophageal junction is not as competent as in humans. As we obtained pH recordings every 5 min and the anatomical structure of rat stomach does not permit spontaneous reflux, it is not possible to conclude that CO_2 insufflation caused gastroesophageal reflux in this study. Further studies are needed to investigate the occurrence of gastroesophageal reflux and alterations in esophageal motility during CO_2 insufflation. We conclude that 1-h laparoscopic procedures with high pressure may alter esophageal pH values without a significant difference.

In conclusion, our results confirm that peritoneal acidosis occurs in response to CO_2 insufflation. The decreased pH values obtained with continuous recordings of the esophagus may have been related to increased IA pressure, rather than metabolic effects of CO_2. Nonetheless, the pH alterations in the esophagus due to CO_2 insufflation were not significantly different; esophageal motility during laparoscopic procedures requires further investigation.

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