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Investigation of the effects of CO_2 insufflation on blood gas values during laparoscopic procedures in pigs

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Abstract: Due to the fact that they produce less post-operative pain and shorter hospitalisation times, laparoscopic surgery procedures are more widely used than many traditional open surgical methods. However, the carbon dioxide gas used to visualise the surgical site during the procedure causes complications such as an increase in the blood CO_2 level and acidosis. In the present study, 12 male pigs were used. Sedation was achieved via intramuscular injection of xylazine at a dose of 2 mg/kg and anaesthesia induction was done via slow intravenous injection of ketamine HCl at a dose of 2 mg/kg. Following endotracheal intubation, general anaesthesia was maintained using isoflurane. Blood samples were collected from the retrobulbar plexus immediately before CO_2 pneumoperitoneum (T_0) and 30 min after insufflation (T_1). Cases were evaluated with respect to pH, pCO_2, HCO^-_3, and SpO_2 levels. The findings obtained revealed that there was a statistically significant difference between T_0 and T_1 measurement times with respect to pCO_2 and HCO^-_3 although there were no significant differences between the other evaluated parameters. As a result, it has been demonstrated that carbon dioxide pneumoperitoneum in laparoscopic surgery increases blood CO_2 levels. Careful anaesthesia, endotracheal intubation, and 100% O_2 inhalation throughout anaesthesia, however, can compensate for this increase. Consequently, with the preservation of blood pH and the stabilisation of pO_2 levels, laparoscopic interventions can be performed without endangering the patient's life.

Key words: Laparoscopy, carbon dioxide, blood gas, pig

Domuzlarda yapılan laparoskopik uygulamalarda CO_2 ensuflasyonunun kan gaz değerleri üzerine etkilerinin araştırılması

Özet: Laparoskopik cerrahi uygulamaları, geleneksel açık cerrahi yöntemlere göre daha az postoperatif ağrı ve daha kısa hospitalizasyon süresine sahip olması nedeniyle yaygın bir kullanım alanı bulmuştur. Ancak bu işlem sırasında operasyon alanının görünür hale getirilmesi için kullanılan karbondioksit gazı, kandaki CO_2 düzeyinin artırmasına ve asidozis oluşumu gibi komplikasyonların ortaya çıkmasına neden olur. Çalışmada 12 erkek domuz kullanıldı. Sedasyon 2 mg/kg dozda xylazine'in kas içi, anestezi indüksiyonu ketamine HCl'nin 2 mg/kg dozda yavaş intravenöz enjeksiyonu ile gerçekleştirildi. Endotrakeal entübasyonları takiben genel anestezi isoflurane ile devam ettirildi. CO_2 pneumoperitoneumundan hemen önce (T_0) ve insuflasyondan 30 dakika sonra (T_1) retrobulbar pleksustan kan örnekleri alındı. Olgular pH, pCO_2, pO_2, HCO^-_3 ve SpO_2 seviyeleri açısından değerlendirildi. Elde edilen bulgular; pCO_2 ve HCO^-_3 düzeyleri arasında T_0 ve T_1 ölçüm zamanları arasındaki farkın istatistiki anlamda önemli, değerlendirilen diğer parametreler arasındaki farkın ise önemsiz olduğunu gösterdi. Sonuç olarak, laparoskopik cerrahide karbondioksit pneumoperitoneumunun, kandaki CO_2 düzeyini yükselttiği ancak, özenli bir anestezi, endotrakeal entübasyon ve genel anestezi süresince %100 O_2 inhalasyonunun sağlanması ile bu artışın kompanze edilebileceği gösterilmiştir. Böylelikle hem kan pH'sının korunması hem de pO_2 düzeyinin stabil kalmasının sağlanmasıyla hasta yaşamının tehlikeye atılmaksızın laparoskopik girişimlerin güvenli şekilde yapılabileceği sonucuna varılmıştır.

Anahtar sözcükler: Laparoskopi, karbondioksit, kan gazları, domuz

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Introduction

In recent years, laparoscopic surgery procedures have been used widely for both the diagnosis and treatment of many diseases. Laparoscopic procedures are preferred to traditional open methods because of their lower post-operative pain, lower morbidity rate, shorter hospitalisation times, and better cosmetic results (1,2).

For the visualisation of the area during laparoscopy and the necessary surgical interventions, pneumoperitoneum is created. This pneumoperitoneum is usually achieved using carbon dioxide. Besides being colourless, odourless, and non-flammable, carbon dioxide is also the gas of choice for its low cost and rapid elimination from the body (1-4).

The high water-solubility of carbon dioxide leads to its absorption into tissues and, in particular, the circulation system. It increases pCO_2 levels in arterial and venous blood while decreasing pH and pO_2 levels. For this reason, it initially causes respiration acidosis, followed by metabolic acidosis and hypercarbia. It changes the acid-base balance. The developing acidosis and hypercarbia pattern can be corrected in 15-40 min with sufficient ventilation (1-3,5).

The pneumoperitoneum procedure also causes diaphragm and respiration movements to decrease and can influence the development of hypercapnia and acidosis. To maintain respiration and the acid-base balance, it is recommended that a slight degree of hyperventilation is induced in patients via endotracheal intubation (6).

Fukushima et al. (4) carried out laparoscopic surgery on dogs by inducing pneumoperitoneum with CO_2. Researchers have reported that within a 30-min period, hypercapnia and acidosis take place together with a compensatory increase in blood bicarbonate.

In another study (7), pneumoperitoneum in pigs was achieved with CO_2 and a significant increase was observed in arterial CO_2 pressure following administration. In the same study, a transient decrease in arterial O_2 pressure was also reported.

In a study carried out on pigs by Suzuki et al. (8), pneumoperitoneum was achieved with CO_2 and the partial pressure of arterial CO_2 and O_2, together with SpO_2 levels, were investigated both before and after the procedure. Parameters evaluated at the end of the study were seen to remain stable throughout the operation.

In another study carried out on pigs (9), it was reported that while pH significantly decreased, pCO_2 levels significantly increased; SpO_2 levels remained at the initial value.

The living organism requires pH to be stable within certain limits in order to accomplish normal physiological functions. A change in these levels leads to systemic function disorders and even the death of the organism (2).

In studies carried out on pigs (2,7,10), it has been reported that immediately after CO_2 insufflation, arterial pH significantly decreases and acidosis develops.

Arterial blood samples give important information about blood-gas and acid-base balances. On the other hand, it may also cause undesired effects such as transient or permanent arterial thrombosis, bleeding, haematoma, and infection (11,12).

Pang et al. (11) have reported that values obtained from lingual venous blood samples may be used instead of arterial blood results and that results obtained from these samples are clinically acceptable.

In a study carried out on rats (13), samples were taken from the sublingual vein and retrobulbar plexus and investigated to see if there was any difference between certain blood parameters. The findings indicated that samples taken from these sites gave similar results.

No previous studies similar to those described above were found either in pigs or in other species in the field of veterinary medicine in Turkey. The aim of this study was to assess the effects of carbon dioxide pneumoperitoneum, used during laparoscopic surgery in veterinary medicine, on blood gas values and to present the results obtained to veterinary practice.

Material and methods

The study was carried out in as part of a course on laparoscopic nephrectomy in pigs organised by İstanbul University's Faculty of Medicine and the Urology Association, and was performed at İstanbul University in the Faculty of Veterinary Medicine, Department of Surgery. A total of 12 male pigs were included in the study. The body weight of these specimens ranged between 30 and 40 kg.

Permission was obtained from the İstanbul University Animal Experiments Local Ethics Committee (Protocol No. 2011/52).

The pigs were starved for 24 h before the operation. Water intake was restricted 2 h before anaesthesia.

Sedation was achieved by intramuscular (IM) administration of xylazine (Rompun 2%; Bayer, Turkey) at a dose of 2 mg/kg. After establishing sedation, a 22-gauge intravenous catheter (Vasofix; B. Braun Melsungen AG, Germany) was placed in the lateral auricular vein of each patient. Anaesthesia induction was achieved by slow intravenous (IV) injection of ketamine HCl (Alfamine 10%; Alfasan International B.V., Woerden, Holland) at a dose of 2 mg/kg.

Following induction of anaesthesia, the cases were intubated using suitable sizes of endotracheal tubes (Rüsch, Germany). General anaesthesia was achieved at an initial concentration of 5% isoflurane together with 100% O_2 and maintained at a concentration of 2.5%. Throughout anaesthesia, respiration was spontaneous in all cases.

All animals were put into dorsal recumbency. The entry site for laparoscopy was shaved and disinfected, after which access was gained into the abdominal cavity through routine entry points. Pneumoperitoneum was achieved using a laparoscopic CO_2 insufflator (Olympus UHI-3, Japan). Intra-abdominal pressure was maintained at a level between 12 and 14 mmHg.

Following general anaesthesia, prior to performing the pneumoperitoneum, blood samples were collected from the retrobulbar plexus located in the medial canthus of the orbit with the aid of an injector. This stage was recorded as T_0.

Approximately 30 min after performing the pneumoperitoneum, a second group of blood samples were collected from the retrobulbar plexus. This stage was recorded as T_1.

The parameters measured in the blood samples collected at both T_0 and T_1 were: pH, pCO_2 (partial pressure of CO_2), pO_2 (partial pressure of O_2), HCO^-_3 (bicarbonate), and SpO_2 (O_2 saturation).

Statistical analysis of the study was done at the Department of Animal Breeding and Husbandry in İstanbul University's Veterinary Faculty.

The differences means between pre- and post-application in terms of pH, pCO_2, pO_2, HCO^-_3, and SpO_2 were analysed using the paired sample t-test method in SPSS 10.0.

Results

Twelve male pigs were used in the study. A rapid and uncomplicated anaesthesia induction was achieved in all cases following the administration of xylazine and ketamine. Respiratory apnoea was not observed in any of the cases. Following loss of the swallowing reflex and loss of tone in the jaw muscles, endotracheal intubation was carried out without any difficulty.

Mean values for the pH, pCO_2, pO_2, HCO^-_3, and SpO_2 for measurements taken at T_0 and T_1 are presented in the Table.

While the pH level was 7.34 ± 0.03 before administration, it was 7.29 ± 0.03 in the measurement taken after administration ($P > 0.05$). The pre-administration pCO_2 level was 50.30 ± 2.49 mmHg, while the post-administration level was 64.41 ± 4.39 mmHg ($P < 0.05$). Pre- and post-administration pO_2 levels were 181.22 ± 65.17 mmHg and 134.92 ± 41.48 mmHg, respectively ($P > 0.05$). While the pre-administration HCO^-_3 level was 27.65 ± 1.54, the post-administration level was 31.41 ± 1.13 ($P < 0.05$). The SpO_2 level before administration was 88.05% ± 1.18, while after administration this level was 82.10% ± 7.24 ($P > 0.05$).

In light of the findings obtained at the end of the study, significant differences were found between measurements taken before and after administration in terms of HCO^-_3 and pCO_2 levels ($P < 0.05$). On the other hand, with respect to the parameters of pH, pO_2, and SpO_2, the effect of the administration was not found to be significant ($P > 0.05$).

Table. The results of blood gas analysis, presented as mean ± standard error: pH, partial pressure of CO_2 (pCO_2) and O_2 (pO_2), HCO^-_3, and O_2 saturation (SpO_2) during CO_2 pneumoperitoneum between 2 time intervals (T) in 12 pigs.

Parameters	Measurement time		Significance
	T_0	T_1	
pH	7.34 ± 0.03	7.29 ± 0.03	P > 0.05
pCO_2, mmHg	50.30 ± 2.49	64.41 ± 4.39	P < 0.05
pO_2, mmHg	181.22 ± 65.17	134.92 ± 41.48	P > 0.05
HCO_3, mM	27.65 ± 1.54	31.41 ± 1.13	P < 0.05
SpO_2, %	88.05 ± 1.18	82.10 ± 7.24	P > 0.05

T_0: immediately before abdominal insufflation
T_1: 30 min after pneumoperitoneum
P < 0.05: The differences between means of T_0 and T_1 measurements are significantly different
P > 0.05: Differences in these measurements are not significant

Discussion

Today, laparoscopic diagnosis and treatment interventions are used widely. This has been influenced by the fact that, compared to traditional open surgical methods, laparoscopic procedures cause less post-operative pain, have a lower morbidity rate, and require shorter hospitalisation periods. However, the carbon dioxide gas used for visualising the surgical site and allowing the necessary manipulation to be carried out during laparoscopy has been seen to produce some undesired effects. The most important complications reported were increased blood CO_2 levels and the development of acidosis.

In the present study, the effects of the CO_2 gas used in laparoscopic interventions in pigs were investigated with regard to pH, pCO_2, pO_2, HCO^-_3, and SpO_2.

Following pneumoperitoneum achieved with carbon dioxide, it has been reported that blood pH decreases and that first respiratory, followed by metabolic, acidosis develops (1-3,5). In this study, however, no significant difference in blood pH was observed in the measurement times for either T_0 or T_1. This result is thought to have emerged as a result of endotracheal intubation being performed in all cases, spontaneous respiration continuing with no occurrence of apnoea or respiratory arrest, and the application of 100% O_2 inhalation.

It has been stated that the easy absorption of carbon dioxide into tissues and especially the circulatory system causes an increase in the CO_2 level of both the arterial and venous blood (1,3,7,9). However, Suzuki et al. (8) reported that CO_2 pneumoperitoneum did not change blood CO_2 levels and that they had obtained stable readings throughout the operation.

In this study, a significant difference was seen to occur between pCO_2 levels recorded at T_0 and those recorded at T_1. Following pneumoperitoneum with CO_2, a significant increase in CO_2 levels was determined. This finding is consistent with results reported in other sources (1,3,7,9).

Carbon dioxide pneumoperitoneum decreases pO_2 levels in arterial and venous blood. In this, the pressure developing in the abdominal cavity, which decreases diaphragm and respiratory movements, also plays a part. However, endotracheal intubation of patients and the application of gentle hyperventilation help to prevent a decrease in pO_2 (6).

Von Delius et al. (7) observed that, following their laparoscopic intervention using carbon dioxide, a transient decrease occurred in pO_2 levels, whereas Suzuki et al. (8) reported that the pO_2 level had remained stable throughout the operation.

In this study, no significant difference was found between the measurement times of either T_0 or T_1 with respect to pO_2, and the oxygen level was seen to remain stable. This finding was compatible with the study carried out by Suzuki et al. (8). This finding was thought to have been a result of the intubation of

patients, application of 100% O_2 inhalation, and the lack of respiratory apnoea.

An increase in the carbon dioxide level of blood leads to a compensatory bicarbonate increase (4). In this study, a significant difference was observed between the measurement times of T_0 and T_1 with respect to bicarbonate levels. This result was thought to have arisen from the compensation of the increase in blood CO_2 level, a finding compatible with the literature (4).

In a study carried out in pigs (8,9), SpO_2 levels were reported to have remained the same during laparoscopic surgery performed with carbon dioxide pneumoperitoneum. Likewise, in this study, no significant change was determined in the measurement times of T_0 and T_1 and the result was seen to be compatible with literary sources (8,9).

Findings obtained at the end of the study have revealed that, during laparoscopic surgery procedures, CO_2 levels in the blood may increase as a natural result of the creation of pneumoperitoneum with carbon dioxide. It is a known fact that ketamine HCl, used for the induction of anaesthesia, causes respiratory apnoea. Slow and careful intravenous injection of ketamine HCl to avoid apnoea, endotracheal intubation of the cases, and providing 100% O_2 inhalation throughout general anaesthesia was found to be significant for the compensation of the increase in blood CO_2. Therefore, by maintaining blood pH and ensuring that pO_2 levels remain stable, it has been concluded that laparoscopic interventions can safely be carried out without putting the patient's life at risk.

References

1. Mynbaev, O.A., Molinas, C.R., Adamyan, L.V., Vanacker, B., Koninckx, P.R.: Reduction of CO_2-pneumoperitoneum-induced metabolic hypoxaemia by the addition of small amounts of O_2 to the CO_2 in a rabbit ventilated model. A preliminary study. Hum. Reprod., 2002; 17: 1623-1629.
2. Bergström, M., Falk, P., Park, P.O., Holmdahl, L.: Peritoneal and systemic pH during pneumoperitoneum with CO_2 and helium in a pig model. Surg. Endose., 2008; 22: 359-364.
3. Jacobi, C.A., Junghans, T., Peter, F., Naundorf, D., Ordemann, J., Müler, J.M.: Cardiopulmonary changes during laparoscopy and vessel injury: comparison of CO_2 and helium in an animal model. Langenbecks Arch. Surg., 2000; 385: 459-466.
4. Fukushima, F.B., Malm, C., Andrade, M.E.J., Oliveria, H.P., Melo, E.G., Calderia, F.M.C., Gheller, V.A., Palhares, M.S., Macedo, S.P., Figueiredo, M.S., Silva, M.X.: Cardiorespiratory and blood gas alterations during laparoscopic surgery for intra-uterine artificial insemination in dogs. Can. Vet. J., 2011; 52: 77-79.
5. Brackman, M.R., Finelli, F.C., Light, T., Llorente, O., McGill, K., Kirkpatrick, J.: Helium pneumoperitoneum ameliorates hypercarbia and acidosis associated with carbon dioxide insufflation during laparoscopic gastric bypass in pigs. Obes. Surg., 2003; 13: 768-771.
6. Tiraboshi, R.B., Domingos, A.L.A., Neto, J.A.D., Paschoal, R.M., Travassos, J., Martins, A.C.P., Suaid, H.J., Cologna, A.J., Jr, S.T.: Is CO2 gas unsufflator necessary for laparoscopic training in animals? Acta Cirurgica Brasileira., 2003; 18: 8-10.
7. von Delius, S., Sager, J., Feussner, H., Wilhelm, D., Thies, P., Huber, W., Schuster, T., Schneider, A., Schmid, R.M., Meinning, A.: Carbon dioxide versus room air for natural orifice transluminal endoscopic surgery (NOTES) and comparison with standard laparoscopic pneumoperitoneum. Gastrointest. Endosc., 2010; 72: 161-169.
8. Suzuki, K., Yasuda, K., Kawaguchi, K., Yoshizumi, F., Inomata, M., Shiraishi, N., Kitano, S.: Cardiopulmonary and immunologic effects of transvaginal natural-orifice transluminal endoscopic surgery cholecystectomy compared with laparoscopic cholecystectomy in a porcine survival model. Gastrointest. Endosc., 2010; 72:1241-1248.
9. Bingener, J., Michalek, J., Winston, J., van Sickle, K., Haines, V., Schwesinger, W., Lawrence, V.: Randomized blinded trial comparing the cardiopulmonary effects of NOTES with Standard laparoscopy in a porcine survival model. Surg. Endosc., 2008; 22: 1430-1434.
10. Liem, T.K., Krishnamoorthy, M., Applebaum, H., Kolata, R., Rudd, R.G., Chen, W.: A comparison of the hemodynamic and ventilatory effects of abdominal insufflation with helium and carbon dioxide in young swine. J. Pediatr. Surg., 1996; 31: 297-300.
11. Pang, D.S.J., Allaire, J., Rondenay, Y., Kaartinen, J., Cuvelliez, S.G., Troncy, E.: The use of lingual venous blood to determine the acid-base and blood-gas status of dogs under anesthesia. Vet. Anaesth. Analg., 2009; 36: 124-132.
12. Kelmer, E., Scanson, L.C., Reed, A., Love, L.C.: Agreement between values for arterial and end-tidal partial pressures of carbon dioxide in spontaneously breathing, critically ill dogs. J. Am. Vet. Med. Assoc., 2009; 235: 1314-1318.
13. Mahl, A., Heining, P., Ulrich, P., Jakubowski, J., Bodadilla, M., Zeller, W., Bergmann, R., Singer, T., Meister, L.: Comparison of clinical pathology parameters with two different blood sampling techniques in rats: retrobulbar plexus versus sublingual vein. Lab. Anim., 2000; 34: 351-361.