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Evaluation of cardiorespiratory parameters in dogs undergoing laparoscopic versus open gonadectomy with spontaneous ventilation anaesthesia: a pilot study

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Abstract

This pilot study aims to compare cardiorespiratory parameters in female dogs that underwent either laparoscopic or open elective gonadectomy with spontaneous ventilation anaesthesia. Records of 77 client-owned female dogs were reviewed. Patients were divided into two groups: laparoscopic surgery (L group, *n* 47) and open abdominal surgery (O group, *n* 30). The end-tidal carbon dioxide, respiratory rate, oxygen saturation, heart rate, non-invasive arterial blood pressure and length of procedure were recorded and statistically evaluated. Once normality of the sample data has been assessed, equality between the groups was analysed with two-sample Student's or Welch's t-test, whether the hypothesis of variance equality, through an F-test, was verified or not. A value of $p < 0.05$ was considered statistically significant. No statistically significant difference was found between groups regarding the end-tidal carbon dioxide, oxygen saturation, respiratory rate, heart rate, systolic and medium arterial pressure values. Mean diastolic pressure was lower in the L group. The procedure length between the two groups was statistically different: laparoscopy was shorter than open surgery. In spontaneously ventilating female dogs, the cardiorespiratory parameters evaluated seem not to be affected by the presence of pneumoperitoneum when intrabdominal pressure is kept between 8 and 10 mmHg. The pilot nature of the study and the shorter laparoscopic surgery length could bias these results. However, in the author's opinion, these findings confirm the interest of laparoscopy and the small impact of this mini-invasive technique in healthy patients.

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Introduction

Laparoscopy is a minimally invasive surgical technique that has become widespread in veterinary and human medicine. The advantages of laparoscopic surgery compared to conventional laparotomy are well described. These include smaller incisions, less postoperative pain, better cosmetic outcome and reduced risk of infection[1,2,3]. The small incisions and limited tissue trauma reduce inflammation and the need for narcotic analgesic, promoting early ambulation and return to eating and self-sufficiency[4]. Moreover, laparoscopy has less impact on the immune system than laparotomy[5]. Reported side effects of laparoscopy compared to open surgery are greater hemodynamic and ventilatory adverse impact[6]. Laparoscopy typically requires insufflation of the abdomen to obtain good organ visualization and sufficient space for manipulation. Carbon dioxide (CO_2) is commonly used to insufflate the abdominal cavity (so-called capnoperitoneum or pneumoperitoneum)[4]. The characteristic of this gas namely – non-flammable, soluble and cost-effective – make it deal for this purpose. Its solubility reduces the risk of fatal gas embolism[7]. The most common side effects related to pneumoperitoneum are oxidative stress and diffusion/absorption of CO_2, which can lead to hypercapnia and metabolic acidosis[6,8,9]. An increase in intra-abdominal pressure (IAP) can lead to decreased venous return, reduced splanchnic organ perfusion, decreased pulmonary compliance, and increase atelectasis of caudal lung lobes in human beings[10,11,12]. However, in healthy human patients with no cardiovascular diseases, there are no significant changes in dead space and shunt fraction when the IAP does not exceed 14 mmHg[11,13]. Similarly, the cardiopulmonary effects of pneumoperitoneum in dogs are similar and well described[6,7,8]. Increasing in systemic vascular resistance and mean arterial blood pressure with little change in heart rate are reported in dogs[6,8]. Transperitoneal CO_2 absorption depends on both the peritoneal surface area and the length of exposure in dogs[7]. Standard of care in veterinary medicine indicates that a safe value for IAP is ≤ 15 mmHg[14]. The purpose of this pilot study is to compare cardiorespiratory parameters, i.e. end-tidal carbon dioxide, respiratory rate, oxygen saturation, heart rate, non-invasive arterial blood pressure, and length of procedure, with a primary interest in end-tidal CO_2 ($EtCO_2$) in female dogs that underwent gonadectomy by either laparoscopy or laparotomy during spontaneous ventilation.

Material and Methods

The study was conduced at Clinica Veterinaria Lago Maggiore, Italy. A hundred and three cases of female,client-owned dogs of mixed breed, with a bodyweight >5 kg were reviewed. The patients were scheduled for elective gonadectomy between January 2016 and December 2018. The body weight and age of the dogs included in the study, mean ± standard deviation (SD), were 17,30 kg ± 11,33 and 27,14 months ± 26,4, respectively. There were 25 (32,47%) mixed-breed dogs and 52 (67,53%) purebred dogs representing 25 breeds. The most common breeds represented in the study were German Shepherd (n = 7 [9,1%]), Jack Russell Terrier (n = 6 [7,8%]), and Labrador Retriever (n = 5 [6,5%]). All enrolled patients were healthy by physical examination and had an unremarkable preoperative minimum database, including CBC and renal biochemical parameters. Written consent for the processing of personal data and written owner informed consent for surgery and anaesthesia was obtained for each patient. Surgical technique (laparotomic vs laparoscopic approach) was based on the owner's choice and only after the explanation of the two different surgical techniques and the relative cost of the procedures. All the surgical procedures considered had to be performed by the same primary surgeon and by the same anaesthesiologist. Only patients maintained in spontaneous ventilation were enrolled in the study. When laparoscopic surgery was performed, IAP applied was between 8 and 10 mmHg. Patients that were positioned in either Trendelenburg or anti-Trendelenburg position were excluded. Anaesthetic and analgesic protocols were tailored to the individual patient and were not considered as inclusion/exclusion criteria. A rebreathing circuit (Datex Homed Aestiva/5) was used for the maintenance of anaesthesia with isoflurane in 100% oxygen (Isoflurane Vet, Merial Italia). All patients were intubated with a cuffed endotracheal tube. The depth of anaesthesia was assessed from evaluation of the palpebral reflex, the position of the eyes, and jaw tone. Measured parameters during the

anaesthesia were: heart rate (HR), end-tidal carbon dioxide ($EtCO_2$), respiratory rate (RR), oxygen saturation (SpO_2), systolic, medium and diastolic non-invasive arterial blood pressure (SAP, MAP, DAP) measured with the Oscillometric method. Neverthless, both the inspired and exhaled fraction of isoflurane, as well as the MAC and the temperature, were recorded but not taken into account in our study. All cardio-respiratory data were obtained with a Multiparametric monitor (Mindray PM9000 series). The length of the procedure was assessed, form start of monitoring in the operative room until the discontinuation of isoflurane administration. The patients were divided into two groups based on the surgical technique they underwent: laparoscopic surgery (L group) versus open surgery (O group). The estimated mean of each variable was calculated (Table 1).

The power analysis performed for the two-sample t-test was performed while designing the study. According to Cohen (1988)[16] and previous literature[14,15] about the expected effect of laparoscopy on the variable registered, they considered an effect size for the power analysis of 0.8. The outcome of the power analysis performed showed that the minimum sample size needed per group was 25. Normality of each variable both in the L group and in the O group was confirmed by the Central Limit Theorem and then verified with the Kolmogorov-Smirnov normality test. After normality was assessed, data were analysed using either two-samples Student's or Welch's t-test, whether the hypothesis of variance equality, through an F-test, was respectively verified or not. A value of $P<0.05$ was considered statistically significant in the tests performed (Table 1).

Results

Seventy-seven female mixed-breed dogs met the inclusion criteria; 47 cases were included in the L group and 30 in the O group. Values of the considered variables are presented as mean ± standard deviation. $EtCO_2$ in laparoscopic and open surgeries was 47.05 ± 6,2 and 45.69 ± 6,68 mmHg respectively; RR was 9,72 ± 5,1 in L group and 10,33 ± 7,86 breaths/minute in O group; SpO_2 was 96.74 ± 1,18 in L group and 96.81 ± 1,21 % in O group; HR in laparoscopic and open surgeries was 106,83 ± 17,57 and 110,29 ± 20,1 beats/ minute respectively; SAP was 97,69 ± 10,23 in L group and 99,98 ± 13,23 mmHg in O group; MAP was 66,20 ± 10,9 in L group and 69,58 ± 12,87 mmHg in O group; DAP was 46,63 ± 9,78 in L group and 50,24 ± 11,18 mmHg in O group; the length of the procedure was 41.58 ± 12.20 and 48.75 ± 7.50 minutes for laparoscopic and open surgery respectively.

The statistical tests were designed setting the null hypothesis of mean equality among the two groups, and the two-sided alternative hypothesis of mean inequality. Since the p-value (relative to the variable x of the L group) was higher than the considered significance level, the null hypothesis cannot be rejected, meaning that means of the variables evaluated in our study can be considered equal between the two groups.

Among the cardiorespiratory parameters of this study, only diastolic arterial pressure showed a significant decrease in the L group (p-value 1.89). The mean surgical time of laparoscopy was statistically shorter (p-value 2.76) compared to open surgery.

Discussion

To the author's knowledge, no studies have been found that compare cardiorespiratory parameters in open and laparoscopic elective gonadectomy in dogs under general anaesthesia on spontaneous ventilation with a maximal IAP of 10 mmHg. This pilot study showed no difference in the cardiorespiratory variables evaluated between the two groups, except for mean diastolic pressure.

The end-tidal CO_2 is an accurate parameter to assess ventilation in anaesthetized animals. Its value closely relates to the arterial partial pressure of carbon dioxide ($PaCO_2$) unless respiratory dysfunction is present (i.e. presence of excessive shunt or dead space)[17]. The general anaesthesia leads to depression of the respiratory function through two different mechanisms: reduction in minute volume (the product of tidal volume multiply by the respiratory rate in a minute), and alveolar hypoventilation because of both alveolar atelectasis and ventilation/perfusion mismatch. The mechanical ventilation is considered to be required in cases of prolonged apnoea, neuromuscular block, thoracic surgery, pulmonary disease (e.g. pulmonary oedema, acute lung injury/acute respiratory distress syndrome), and in other conditions that reduce

Table 1. The mean ± standard deviation of the cardiorespiratory parameters in 77 female dogs undergoing laparoscopic (L group = *n* 40) vs open (O group= *n* 37) gonadectomy in spontaneous ventilation anesthesia. In bold, p < 0.05 between the groups.

Variable	Statistic.t (student test)	parameter.df (degree of freedom)	estimate mean of I.	estimate mean of O	p.value (%)	method
HR (beats minute^{-1})	-1.3481	368.00	106.83± 17,57	110.29 ± 20,10	17.84	TS*
$EtCO_2$ (mmHg)	1.5516	124.70	47.05 ± 6,20	45.69 ± 6,68	12,33	WTS†
RR (breath minute^{-1})	-0.4811	126.00	9.72± 5,10	10.33 ±7,86	63,13	TS*
SpO_2 (%)	-0.3979	148.01	96.74 ±1,18	96.81 ±1,21	69,12	WTS†
SAP (mmHg)	-1.4759	125.74	97.69±10,23	99.98 ± 13,23	14,25	WTS†
MAP (mmHg)	-1.9452	339.00	66.20± 10,90	69.58 ± 12,87	5,26	TS*
DAP (mmHg)	-2.3584	339.00	46.63 ±9,78	50.24 ± 11,18	1,89	TS*
Surgery Lengtht (minutes	-2.2246	151.00	41.58 ±12.20	48.75 ± 7,50	2,76	TS*

*= Two Sample t-test

†= Welch Two Sample t-test

HR, heart rate: $EtCO_2$, end-tidal carbon dioxide; RR, respiratory rate; SpO_2, oxygen saturation; SAP, systolic arterial blood pressure; MAP, medium arterial blood pressure; DAP, diastolic arterial blood pressure

pulmonary and/or thoracic compliance[17]. A rise in $PaCO_2$ is expected during laparoscopic surgery[4], and the increase of $EtCO_2$ reaches a plateau after 15-30 minutes from the beginning of insufflation[18,19]. The increase is caused by time-dependent transperitoneal absorption of CO_2 and elevated IAP. It has been demonstrated that transperitoneal CO_2 absorption depends on both the peritoneal surface area and the length of exposure[7,15,20,21]. At the same time, pneumoperitoneum can also alter pulmonary functionality when IAP is ≥15 mmHg[6]. In standard laparotomic procedures in dogs, an alveolar recruitment manoeuvre followed by 5 cmH_2O of positive end-expiratory pressure (PEEP) was adequate to resolve anaesthesia-induced pulmonary atelectasis, as indicated by computed tomography studies[22]. Thus, positive pressure ventilation is highly recommended in animals undergoing laparoscopy in order to cope with the increased work of breathing-related to the pneumoperitoneum and to optimize lung ventilation for the increased elimination of CO_2[14,15]. However, during spontaneous ventilation, the compensatory mechanism represented by the interaction between thorax, diaphragm, and abdomen acts to minimize the respiratory embarrassment caused by a finite degree of abdominal distention[23].

Nevertheless, in healthy human patients, rising of $PaCO_2$ seems to be primarily related to the absorption from the peritoneal surface rather than the reduction of ventilation during endosurgery[24,25,26,27]. In this study, any statistical difference was not found in mean $EtCO_2$ and mean respiratory rate between laparoscopic and open surgery. It might be assumed that, even if ventilation was not explicitly investigated in our study, our data confirm the results of previous studies in which both tidal volume and minute ventilation decrease without changing respiratory rate in spontaneous ventilating animals underwent to laparoscopic surgery[20]. In patients of the L group, pneumoperitoneum never did rise above 10 mmHg, so that the adverse effects of IAP increase were minimal. Average surgical time was 41.58 minutes for laparoscopy and 48.75 minutes for open surgery. Length of procedure and IAP between 8 and 10 mmHg could have had a role in the ventilatory findings of this study, because of small transperitoneal absorption of CO_2 and a minimal interference on spontaneous ventilatory mechanics of the patients.

A fall in the arterial partial pressure of oxygen (PaO_2) is expected with CO_2 insufflation to an IAP of 10-15 mmHg[4,6]; however, in anaesthetized animals receiving high oxygen concentrations, the decrease of PaO2 may have minimal clinical significance[28]. Recent studies showed a slight improvement in PaO_2: FIO_2 (+7%) and a significant reduction in Shunt fraction (-34%) during the pneumoperitoneum[14]. In attempting to understand this mechanism, Strang *et al.* , demonstrated that improved gas exchange and oxygenation is caused by the redistribution of blood flow away from collapsed lung tissue during pneumoperitoneum, resulting in a better ventilation/ perfusion match[29]. A likely but not yet proven explanation is enhanced hypoxic pulmonary vasoconstriction, possibly mediated via increased $PaCO_2$ [30]. In our study, the mean values of SpO_2 did not show any statistical difference between the groups.

The hemodynamic impact of laparoscopy could be significant when IAP is above 15 mmHg[6,23]. In this case, the consequent reduction of cardiac output can eventually lead to reduced abdominal organs perfusion and oliguria[4]. Consequently, compensatory mechanisms such as the increase in both heart rate and mean arterial pressure[4] are triggered by the decrease of a venous return due to pressure of the capnoperitoneum on abdominal vessels and the sympathetic stimulus caused by the absorption of CO_2[31]. There was no statistical difference between the L group and the O group in values of heart rate and arterial blood pressure, except for diastolic pressure. The Mean diastolic pressure was lower in the L group with a statistically significant difference (p-value 1,89). It can be speculated that the magnitude of IAP applied, which in this study never rises above 10 mmHg, is responsible for the absence of differences in HR and blood pressure between two groups. Mechanisms of compensation are lower when the venous return and cardiac output seems to be maintained. The lower nociceptive response evocated during laparoscopy compared to open surgery can also have a role in these results.

The retrospective nature of this study may have influenced the results obtained. The limits to be considered are mainly related to the non-homogeneous

sample (i.e. the variability of patients in age, and size) and variability of the anaesthetic protocol (drugs type and timing of administration could influence ventilation of the patients). Age can account for different compliance on pulmonary parenchyma, and the size (different breeds) of the patients can influence the absorption of CO_2 by changing in peritoneal surface area. Bodyweight and age of the dogs included in the study (mean ± SD) were 17,30 kg ± 11,33 and 27,14 months ± 26,4; the body weight and age (mean ± SD) of the L group were 15,90 kg ± 10,80 and 15,61 months ± 15,39; the body weight and age (mean ± SD) of the O group were 19,50 kg ± 11,96 and 41,80 months ± 25,63. Further study should select a more homogeneous sample of dogs both in age and in size to minimize the bias. The anaesthetic and analgesic protocol was not considered an exclusion criterion, but it has been demonstrated that opioids can affect ventilation much more than other drugs, such as dexmedetomidine[32,33]. For further studies, the authors suggest to avoid opioids and consider local blocks.

The hemodynamic changes can be better assessed through invasive arterial blood pressure due to the rising of intra-abdominal pressure. Moreover, the data analysis, despite having considered the duration of the surgery, did not consider the duration of the pneumoperitoneum. Duration of pneumoperitoneum both itself and the length of the surgical procedure are interesting points to consider in further studies to better understand the role of transperitoneal absorption of CO_2 and hypoventilation during laparoscopy as a reason of $PaCO_2$ changes. It could be interesting to assess ventilation at specific points of procedures (after induction, immediately before insufflation, at the beginning, and immediately before resolution of pneumoperitoneum) to evaluate both the differences between the groups and the trend of the parameters assessed in the study. The ventilatory function may be better assessed by arterial blood gas analysis. This method better reflects the ventilatory status of the patient since it considers other parameters such as shunt fraction and actual blood content of CO_2. The study aimes to assess any difference in cardiorespiratory parameters due to the presence or absence of pneumoperitoneum in spontaneous ventilation anaesthesia. Even if all the patients enrolled in the study were ASA-1 or -2 and were clinically healthy, no preoperative thoracic radiographs were available. The depth of anaesthesia was assessed clinically, and the end-tidal ISO was not taken into account in the study. The use of spirometry or a recruitment manoeuvre could have clarified an adequate or not ventilation of the patient. However, in humans, it has been showed that the recovery of respiratory function seems to be quicker in laparoscopic surgery compared to traditional technique[34,35]. Furthermore, it could be the impact of laparoscopy on respiratory function in the postoperative period and the recovery of breathing also in veterinary patients.

This study does not allow to draw definitive conclusions on the impact of the pneumoperitoneum on ventilation and hemodynamic during laparoscopic surgery in dogs. Though, these data could suggest a small impact of laparoscopy compared to open surgery when IAP is kept ≤ 10 mmHg. These data seem to confirm those reported in a recent prospective study, comparing laparoscopy and a gasless technique, in which respiratory and hemodynamic variables of dogs were not statistically different between groups[36].

Conclusions

This study aimed to investigate the influence on cardiorespiratory parameters of laparoscopic surgery compared to the laparotomic approach in healthy dogs with spontaneous ventilation anaesthesia. These preliminary results suggest the small impact of the pneumoperitoneum when intra-abdominal pressure is maintained between 8 and 10mmHg. It is the author's opinion that these findings emphasize the benefits of laparoscopic surgery over its possible side effects.

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Competing Interests

The authors declare that they have no competing interests.

Availability of Data and Materials

All data generated or analysed during this study are included in this article.

Consent for Publication

Not applicable

Ethics Approval and Consent to Participate:

Not applicable

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Abbreviations

L group - laparoscopic group

O group - open abdominal surgery group

CO_2 - carbon dioxide

IAP - intra-abdominal pressure

$EtCO_2$ - end-tidal carbon dioxide

SD - standard deviation

CBC - complete blood count

MAC - minimum alveolar concentration

HR - heart rate

RR - respiratory rate

SpO_2 - oxygen saturation

SAP - systolic arterial blood pressure

MAP - medium arterial blood pressure

DAP - diastolic blood pressure

$PaCO_2$ - arterial partial pressure of carbon dioxide

PaO_2 - arterial partial pressure of oxygen

ASA - American Society of Anaesthesiologists physical status classification system

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