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Cardiac Effects of Carbon Dioxide Pneumoperitoneum in Veterinary Laparoscopy for Dogs

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ABSTRACT

Despite all of the advantages of laparoscopic surgery, there remain certain concerns. An increased intra-abdominal pressure (IAP) exerted by CO_2 pneumoperitoneum has adverse effects on all organs and systems especially on the circularity system and cardiac function. To understand effect of IAP study was undertaken on twelve female mongrel dogs brought for laparoscopic ovariohysterectomy. All dogs were sedated with butorphanol, induced with propofol and maintenance of anesthesia was done with isoflurane. All dogs underwent a detailed systemic investigation protocol including echocardiographic examination. Physiological parameters such as rectal temperature decreased significantly throughout anaesthetic period and come to normal after complete recovery. Heart rate, pulse rate and respiratory rate was decreased significantly after induction of anaesthesia and increased after insufflation of CO_2. Echocardiographic parameters like EF and CO were decreased significantly after induction of anaesthesia by 9% and 33% respectively and after insufflation of CO_2 by 8% and 5% respectively. However, all other parameters (FS and SV) showed no significant changes. In conclusion, effects of CO_2 pneumoperitoneum and anaesthesia on cardiac function are mild and of transient duration in healthy dogs.

Key words: CO_2 pneumoperitoneum, Echocardiography, Increased intra-abdominal pressure, Laparoscopic surgery.

The advancement of minimally invasive surgery in veterinary medicine practice is at par with human medicine. Laparoscopic surgery has significant benefits as compared to traditional conventional open surgery, including less trauma, less tissue manipulation, smaller incisions faster recovery, less time under anaesthesia, less bleeding, less invasiveness and superior visibility (Gower and Mayhew, 2008). The laparoscopic ovariohysterectomy (LOVH) for pets offers a minimally invasive surgical alternative for clients. LOVH provides potential benefits over OVH, such as reduced discomfort, a lower chance of dehiscence, haemorrhage and a lower risk of postoperative wound sequelae (Davidson *et al*., 2004).

Pneumoperitoneum, created by insufflating gas to provide space for instruments and a camera, is the key step in laparoscopy (Mayhew *et al*., 2018). Carbon dioxide (CO_2) is the preferred gas for insufflation (Neuhaus *et al.,* 2001).

Although laparoscopic surgery has numerous benefits, there are some concerns due to increased intra-abdominal pressure and CO_2 absorption, impacting the cardiovascular system with risks of hypertension, hypotension, arrhythmias, gas embolism and cardiac complications.

Increased intra-abdominal pressure (IAP) impacts various cardiorespiratory parameters such as heart rate, cardiac output, stroke volume, inferior vena cava flow, systemic vascular resistance, arterial partial pressure of oxygen, oxygen delivery, mean arterial pressure, pulmonary compliance and minute breathing (Ivankovich *et al.,* 1975; Duke *et al.,* 1996). Absorption of CO_2 during laparoscopy leads to systemic acidosis and hypercapnia, causing vasodilation, myocardial depression and sympathetic stimulation (Koivusalo *et al.* 1998). Cardiac output dropped to less than 80% of baseline with increased intra-abdominal pressure due to CO_2 insufflation, with the Trendelenburg position having mixed effects, both alleviating and worsening this impact (Williams and Murr, 1993).

Cardiac conditions are typically diagnosed peri-operatively using clinical signs, physical examinations, radiography and heart and lung auscultation. Echocardiography offers a more detailed non-invasive diagnostic tool, enabling visualization of heart structure, movement and blood flow. It operates through sound wave

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interactions, using reflection and scattering to evaluate heart function (Boon, 2011; Gugjoo *et al*., 2013). Key measurements for assessing cardiac function include ejection fraction (EF), fractional shortening (FS), stroke volume (SV) and cardiac output (CO), derived from M-mode echocardiography (Boon, 2011).

Cardiopulmonary depression is expected due to anaesthetic procedure as well as pneumoperitoneum, hence this research was undertaken to monitor the cardiac functioning during anaesthetic as well as pneumoperitoneum by echocardiography and to evaluate the changes in cardiac functioning, if any.

Selection of patients

12 healthy female mongrel dogs approximate age ranges from 1.5 to 3 years presented for laparoscopic ovariohysterectomy to the department of Department of Veterinary Surgery and Radiology, Mumbai Veterinary College, Parel, Mumbai included in the study after the consent from pet owners and college ethical committee had been obtained.

Preparation of patients

All the patients were admitted one day before examination to get acclimatize in new environment. The patients were kept nil by mouth (NBM) for twelve hours. Physical, clinical examinations as well as electrocardiographic and echocardiographic examination were carried out before subjecting the dogs to anaesthesia and pneumo peritoneum. The right parasternal location from 3rd to 6th intercostal area was prepared aseptically for laparoscopic procedure.

Anaesthesia

All the dogs were sedated with butorphanol, anaesthesia induced with propofol and maintained with isoflurane.

Surgery

The ovariohysterectomies were performed using laparoscopic techniques via three trocars, one placed midline and two lateral. Pneumoperitoneum was induced by insufflating carbon dioxide at 12 mm Hg pressure at flow rate of 2 L/min. The average time for surgery was 52 minutes (range 45-65). No perioperative complications occurred and the patients were discharged after 7 days of post-operative care.

Instrumentation

The parameters such as Rectal temperature, Heart rate, Respiration rate, Pulse rate and blood pressure was recorded by multipara monitor (GE B40 patient monitor).

Echocardiography

A multi-frequency (1-5 MHz) cardiac probe was used and recordings were made using AEROSCAN CD 10 PRO ultrasound machine. M mode echocardiographic recordings of left ventricular short axis were recorded at the level of midpapillary muscles (Fig 1, Fig 2).

Study protocol

Measurements such as HR, PR, RR, RT, BP and m mode left ventricular echocardiography were made pre-operative period before anaesthesia, then after induction of anaesthesia. After recording their measurements, pneumoperitoneum was established and same all measurements were performed. At the end after dogs recovered from anaesthesia all the measurements were taken one last time.

Calculations

The data obtained from m mode measurements were used for calculating EF, FS, SV and CO.

$$\text{LV diastolic volume (LVVd)} = \frac{7 \times (\text{LVIDd})^3}{2.4 + \text{LVIDd}}$$

$$\text{LV systolic volume (LVVS)} = \frac{7 \times (\text{LVIDs})^3}{2.4 + \text{LVIDs}}$$

$$\text{Ejection fraction (\%) EF} = \frac{\text{LVVd - LVVs}}{\text{LVVd}} \times 100$$

$$\text{Fractional shortening (\%) FS} = \frac{\text{LVIDd - LVIDs}}{\text{LVIDd}} \times 100$$

$$\text{Stroke volume (ml) SV} = (\text{LVVd}) - (\text{LVVs})$$

$$\text{Cardiac Output (ml) CO} = \text{SV} \times \text{HR}$$

Statistics

Data were presented as mean. The data generated during the study was analyzed by one way analysis of variance.

12 healthy female mongrel dogs approximate age ranges from 1.5 to 3 years with average body weight 15.76 kg were included in this study. Out of 12, in 2 dogs apnoea was observed but no other anaesthesia related complications. Measurements noted at pre-operative period acts as reference range and changes were measured comparing with it.

Physiological parameters

HR, PR, RR, Rectal temperature and MAP at different intervals were shown in Table 1.

Heart rate and pulse rate decreased significantly after induction of anaesthesia and they increased significantly after insufflation. However, there was a non-significant increase in heart rate and pulse rate was observed after the end of surgery. While the values of heart rate and pulse rate were within normal physiological limit at various intervals. A significant decrease in the respiratory rate was noticed after induction of anaesthesia. However, a significantly increase in respiratory rate was noted after creation of pneumoperitoneum and also during recovery from anaesthesia. There was significant decrease in the rectal temperature from after induction of anaesthesia. The MAP decreased significantly after induction of anaesthesia as compared to pre-induction value and increased significantly after insufflation, there was increase in MAP noticed after surgery.

Echocardiographic parameters

All left ventricular ejection phase indices obtained from m mode dimensional measurements were represented in Table 2.

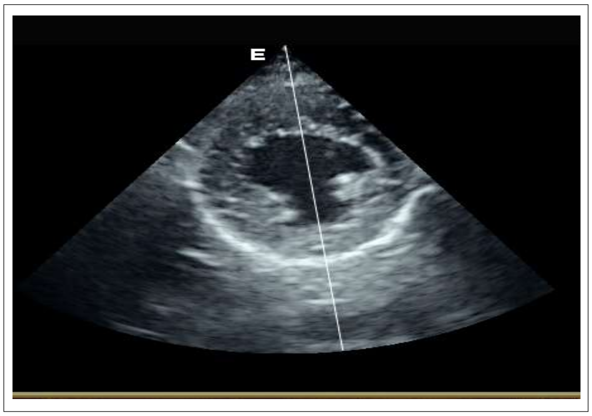

Fig 1: Echocardiogram showing right parasternal short axis view at papillary muscle level (Mushroom shape appearance).

There was a significant decrease in EF of around 9% after induction of anaesthesia, further decrease of around 8% after insufflation, followed by increase at the end of surgical procedure. The cardiac output significantly decreases around 33% after induction of anaesthesia, furthermore decreased around 5% after insufflation during surgery, but all changes remain with in physiological limits. No significant changes were observed in FS and SV after induction of anaesthesia and after insufflation.

An adequate amount of blood must be pump out of heart to meet peripheral perfusion of tissue and meet metabolic need of body. This pumping activity represented by assessing left ventricular ejection phase indices. The pumping activity depends on preload, afterload, contractibility, dispensability, coordinated contraction and heart rate (Boon, 2011).

Preload is the force stretching myocardium and is depend up on amount of blood distending the ventricles at end-diastole. Propofol caused the marked decrease in blood pressure due to its negative inotropic effect, leads to reduction in venous return and that may result in decrease

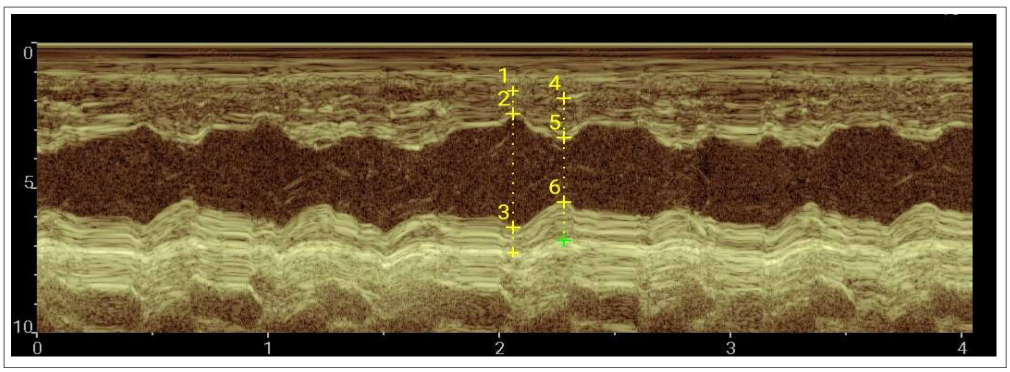

Fig 2: M mode echocardiogram dimensions (1.IVSd, 2. LVIDd, 3. LVPWd, 4. IVSs, 5. LVIDs and 6. LVPWs.).

Table 1: Physiological parameters.

Physiological parameters	Before induction of anaesthesia	After induction of anaesthesia	After pneumoperitoneum of 12 mm Hg intra -abdominal pressure	After recovery from anaesthesia
HR (beats/minute)	121.83	96.58	120	130
PR (pulse/minute)	121.66	96.44	120.4	130.41
RR (respiration/minute)	30.08	20.33	27.33	36.16
RT (F°)	100.8	98.25	97.73	101.05
MAP (mm Hg)	99.72	83.06	89.07	92.97

Table 2: Echocardiographic parameters.

Parameters	Before induction of anaesthesia	After induction of anaesthesia	After pneumoperitoneum of 12 mm Hg intra -abdominal pressure	After recovery from anaesthesia
Ejection fraction (EF) (%)	65.88	59.77	54.77	62.46
Fractional shortening (FS) (%)	34.16	30.91	27.73	32.59
Stroke volume (SV) (ml)	24.42	21.71	17.07	21.96
Cardiac output (CO) (ml)	3148.78	2103	1991.28	2777.44

in preload after induction of anaesthesia. EF and FS both are directly related to preload so this might be the reason for decrease in EF and FS after induction of anaesthesia with propofol in present study. Hence the stroke volume also decreases and ultimately cardiac output. Carlier *et al.* (1989) observed decrease in blood pressure, stroke volume and cardiac output after 3 minutes of propofol administration. Cardoso *et al*. (2018) reported a significant decrease in EF, FS and Cardiac output in dogs anesthetized through different anaesthetic protocols such as combination of drugs diazepam, etomidate, ketamine and propofol. Kellihan *et al*. (2015) noted a decrease in EF, FS and cardiac output in dogs sedated with recommended dose of dexmedetomidine after 20 min.

The post-pneumoperitoneum cardiac indices are influenced by myocardial contractibility, venous return as preload and peripheral pressure as afterload. However, the depth of anaesthesia, transfusion volume, sympathetic stimulation, vagal nerve stimulation, type of pneumoperitoneum gas and intra-abdominal pressure has influence on these factors. In this study cardiac output and EF decreased significantly after insufflation of CO_2 and another indices has non-significant effects. A number of investigators studied the hemodynamic alterations that caused due to CO2 pneumoperitoneum both in human as well as in animals. Williams and Murr (1995) demonstrated that cardiac output was decreased by pneumoperitoneum of 15mm Hg and 30 mm Hg of intra-abdominal pressure. Ishizaki *et al.* (1993) reported decrease in cardiac output and increase in MAP at 16 mm Hg of intra-abdominal pressure. In pigs Ho *et al.* (1992) reported an increase in mean arterial pressure, decrease in stroke volume and no change in cardiac output at pneumoperitoneum of 15 mm Hg. Marathe *et al.* (1996) reported intra-abdominal pressure greater than 15 mm Hg decreased cardiac output, however MAP remain unchanged. Shih *et al.* (2015) demonstrated low pressure abdominal insufflation developed hypercapnia, diminished respiratory compliance and reduced stroke volume. Even though most of these changes were ephemeral and corrected after pneumoperitoneum was discontinued. In present study mean arterial pressure increased, EF and cardiac output both decreased after insufflation of CO_2 at 12mm Hg of intra-abdominal pressure where as other parameters showed non-significant changes. These results were in similar to Ishizaki *et al.* (1993) and Shih *et al.* (2015).

Physiological parameters such as Heart rate (HR), Respiration rate (RR), Pulse rate (PR) increased after insufflation of CO_2 could be the result of the compensatory resonance to the decrease venous return and increase in the abdominal pressure or absorption of CO_2. Significant decrease in the rectal temperature was noted in present study which might be due to the result of the anaesthetic drugs used, heat loss from convection and evaporative cooling in the abdominal cavity due to CO_2 insufflation. Grimm (2015) stated that hypothermia may be caused by the suppression of muscular activity, metabolism and hypothalamic thermostatic mechanisms by anaesthetic drugs. Jacobs *et al.* (1999) revealed that evaporative cooling, *i.e*. heat loss from liquid water to saturate the insufflated CO_2 particles was the most important cause of decrease in the temperature during laparoscopic procedure.

CONCLUSION

The pneumoperitoneum with CO_2 at 12 mm Hg of intra-abdominal pressure reduces the cardiac output and ejection fraction, but change remain with in physiological limits and also regains its original value after complete recovery of patient. On the contrary other parameters (FS and SV) shows no significant change. Further study on cardiac function during laparoscopic ovariohysterectomy with CO_2 pneumoperitoneum, transesophageal probe will be more useful for better evaluation of cardiac effects.

Conflict of interest

All authors declared that there is no conflict of interest.

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