Original Article

Correspondence to:

João Luiz Moreira Coutinho Azevedo – Azevedo JLMC

M.D., Ph.D., Associate Professor, Federal University of São Paulo, Brazil.

Division of Minimally Invasive Surgery, Department of Surgery, Federal University of São Paulo.

R. Botucatu 740 – São Paulo, SP, Brazil Tel: 55 11 5549-7495 Fax: 55 11 5571-2472.

E-mail: jozevedo.dcir@epm.br

Title: Relationship of arterial and exhaled CO_2 during elevated artificial pneumoperitoneum pressure for introduction of the first trocar.

Authors:

O. H. M. Hypolito[1] - octaviohypolito@hotmail.com

J. L. M. C. Azevedo[1] - jozevedo.dcir@epm.br

S. A. Miyahira[2] - susana_miyahira@uol.com.br

F. Scarpelli[2] - fabiscarpelli@yahoo.com.br

O. M. Becker Junior[1] – otaviobecker@hotmail.com

A. C. C. G. Machado[2] - afonso.guedes@yahoo.com.br

O. C. Azevedo[1] - ozevedo@terra.com.br

G. C. Azevedo[2] – glzevedo@terra.com.br

B. Marigliani[3] - biancamagli@hotmail.com

J. F. Borborema[2] - joseborborema@hotmail.com

L. Bernardes[3] - lindabernardes00@gmail.com

G. P. S. Miguel[1] - gsoaresp@terra.com.br

1. M.D. PhD - Federal University of São Paulo, Sao Paulo, Brazil.

2. M.D. - Federal University of São Paulo, Sao Paulo, Brazil.

3. Federal University of São Paulo, Sao Paulo, Brazil.

ABSTRACT

The present study evaluated the correlation between arterial CO_2 and exhaled CO_2 during brief high-pressure pneumoperitoneum. Patients were randomly distributed into two groups: P12 group (n=30) received a maximum intraperitoneal pressure of 12mmHg, and P20 group (n=37) received a maximum intraperitoneal pressure of 20mmHg. Arterial CO_2 was evaluated by radial arterial catheter and exhaled CO_2 was measured by capnometry at the following time points: before insufflation, once intraperitoneal pressure reached 12mmHg , 5 minutes after intraperitoneal pressure reached 12mmHg for the P12 group or 20mmHg for the P20 group, and 10 minutes after intraperitoneal pressure reached 12mmHg for the P12 group or when intraperitoneal pressure had decreased from 20mmHg to 12mmHg, for the P20 group. During brief durations of very high intraperitoneal pressure (20mmHg), there was a strong correlation between arterial CO_2 and exhaled CO_2. Capnometry can be effectively used to monitor patients during transient increases in artificial pneumoperitoneum pressure.

Key Words: Intraoperative monitoring; laparoscopy; pneumoperitoneum; surgical instruments

Surgical trauma is reduced by minimally invasive surgery, with consequent attenuation of metabolic responses and benefits to the patient[1] such as a reduction of pain[2] better cosmetic outcome, shorter period of hospitalization[3] early resolution of postoperative gastrointestinal paralysis (adynamic ileus)4 and reduced changes in pulmonary function.5 There is a net immunologic advantage of laparoscopic surgery.[6] These benefits are particularly pertinent to video laparoscopy. The gas most used for insufflations into the peritoneal cavity for creation of pneumoperitoneum is CO_2, because of its low cost, noninflammability, and known metabolism in the human organism.[7] Moreover, carbon dioxide insufflations has an inhibitory effect against bacterial infection.[8] However, because it is relatively new, the laparoscopic surgical technique is still the subject of some controversy.[9] In particular, the best way to access the peritoneal cavity for initiation of the pneumoperitoneum has yet to be determined.[10] Currently, the Veress needle puncture[11] is the technique utilized most often.[12]

Most of the complications in laparoscopic surgery occur early in the procedure during the introduction of the Veress needle and the first trocar. This step may cause multiples complications.[13] Therefore, we seek ways to prevent iatrogenic complications, such as establishing an artificial system that keeps the pneumoperitoneum pressure very high for a duration sufficient to introduce the first trocar by the closed method. This method contributes to the protection of intra-abdominal structures without causing clinical complications.[14]

Continuous monitoring of the arterial blood gas exchange during laparoscopy is imperative, especially while the intraperitoneal pressure (IPP) is highly elevated. The insufflation of a highly diffusible foreign element (CO_2) in the peritoneal cavity can cause disturbances to gas exchange in the alveoli and intraperitoneal capillary network.[15-20] Arterial blood gas monitoring is routinely carried out by capnometry (measuring the concentration of exhaled carbon dioxide, $EtCO_2$).[21-23] Even though capnometry is an indirect way of determining CO_2 concentration in arterial blood, studies have shown a correlation between $EtCO_2$ and PaCO2[32] at IPPs below 15 mm Hg. However, it is still unknown whether this correlation holds at higher IPP.

Therefore, it is extremely important to determine the best method for measuring CO_2 concentration during artificial high-pressure pneumoperitoneum to improve the safety of this technique. The present study evaluated the correlation between $PaCO_2$ and $EtCO_2$ during brief high-pressure pneumoperitoneum.

METHODS

This prospective, randomized clinical trial was approved by the Ethics Committee of the Federal University of São Paulo (UNIFESP) under number 1.219/07 and by the Research Ethics Committee of the University of Taubaté (UNITAU) under number 007/2.007. All patients signed an informed consent form. The study was conducted at the Dr. José de Carvalho Florence Municipal Hospital (HMJCF) in São José dos Campos, SP, Brazil.

Between October 2007 and May 2008, we enrolled 67 patients scheduled for elective laparoscopic surgery. The studied patients were aged between 20 and 79 years, classified according to their physical condition as ASA I or ASA II, and had no history of abdominal surgery in organs located in the supramesocolic abdomen floor, no previously diagnosed peritonitis and a body mass index (BMI) of less than 35. Patients were randomly assigned either to a group P12 (n = 30) when they received insufflation with 12 mmHg, or to a group P20 (n =37). Patients in the P12 group were between 22 and 72 years old, with an average age of 47.2 years and a standard deviation of ±14.5. Patients in the P20 group were 20-79 years old, with an average age of 46.5 ±15 years. The mean BMI of the P12 group was 26.3 with a standard deviation of ±4 and amplitude between 20.2 and 33.4; in the P20 group, these values were 26.2, ±3.8, and 17.5-34.6, respectively. There were 25 women and 5 men in the P12 group, and 30 women and 7 men in the P20 group. There were no statistically significant differences in the demographic data between groups ($P>0.05$).

Patients received pre-anaesthetic evaluation at the clinic before surgical intervention. No patient received pre-anaesthetic medication. Allen's test, as modified by Asif,24 was performed before anaesthesia was administered.

Patients were hydrated with lactated Ringer's solution after venipuncture with an 18G catheter according by anaesthesiologist criteria. Lines were installed to monitor cardioscopy data (five leads ECG), pulse oximetry, noninvasive blood pressure and intratracheal pressure and to perform capnometry. All patients received general anaesthesia. Anaesthesia was induced with sufentanil 0.5mcg/kg, rocuronium 0.6mg/kg and propofol 2mg/kg. Anaesthesia was maintained with sevoflurane in a mixture of oxygen and compressed air. All patients were mechanically ventilated using a ventilator with a timed cycle. Anaesthesia and monitoring were performed with an Ergo System PC 2700 - Shogum Takaoka and a Dräger Fabius GS anaesthesia workstation with Dixtal monitors (model DX 2010). Ventilation was carried out so that the initial fraction of inspired oxygen was 60%, final positive exhaled pressure was 4cmH_2O, flow volume was 7mL/kg, respiratory rate was 15 breaths per minute and the inspiration/expiration ratio was 1:2.

Six patients were excluded from the study for the following reasons: one patient had bronchospasms after induction, in one patient the intubation was difficult and it was necessary to use additional procedures not covered in the study protocol, in two patients the third attempt to catheterize the radial artery failed and in two patients blood samples were lost due to clot formation.

Pneumoperitoneum was induced by the closed technique. The abdomen was punctured with a Veress needle, and the flow of CO_2 was set to 1L per minute. $EtCO_2$ and $PaCO_2$ were evaluated in both groups at the following time points: before insufflation (M0), once the IPP reached 12mmHg (M1), 5 minutes after the IPP reached 12mmHg for the P12 group or 20mmHg for the P20 group (M2) and 10 minutes after the IPP reached 12mmHg for the P12 group or when IPP had decreased from 20mmHg to 12mmHg, 10 minutes after M1, for the P20 group (M3).

Arterial blood gas analysis was performed with a Rapidlab 348 Bayer Health Care, Model 348 pH/Blood Gas Analyzer SN 6678. Patient cardiac rhythm, pulse oximetry, end-tidal ($ETCO_2$), mean arterial pressure and intratracheal pressure (measure by anaethesia workstation in cmH_2O) were monitored during the surgical procedure. In the recovery room after anaesthesia, patient heart rate, cardiac rhythm, mean arterial pressure, pulse oximetry, consciousness and muscle activity were monitored until the patient was discharged to the ward.

Position measurements for continuous variables and frequencies for categorical variables were used for the descriptive statistical analysis. The chi-square test was used to compare age, BMI and the gender correlation between the groups. Differences were considered to be statistically significant when P>0.05. To correlate $EtCO_2$ with $PaCO_2$ for each time point analysed, the Spearman correlation coefficient was used. The correlations were considered to be statistically significant when P>0.05.

RESULTS

There was a strong correlation between $EtCO_2$ and $PaCO_2$ for both the P20 and P12 groups (Table 1, Table 2, Figure 1 and Figure 2). The various parameters measured in this study did not surpass values considered normal in healthy populations undergoing surgical procedures. All values remained normal until patients were discharged after the post-anaesthesia recovery.

DISCUSSION

Previously, analysis through non invasive data did not show significant clinical modifications during laparoscopic procedures with brief transitional high-pressure artificial pneumoperitoneum for the introduction of the first trocar.[14] In this study, we analysed physiological changes and gas exchange during these moments.

Patients were divided into two groups: P12, receiving a maximum IPP of 12mmHg, and P20, receiving a maximum IPP of 20mmHg. The P12 group was the positive control group in which all biological indices during the surgical procedure with standard IPP (12mmHg) were analysed. Thus, the purpose of including the P12 group in this study was to isolate the role of high pressure (20mmHg) in changes that were observed in the P20 group. The parameters were evaluated in the P12 group to exclude duration of pneumoperitoneum as the determining factor in biological changes observed in the P20 group. Thus, it is possible to attribute differences found in the P20 group compared to the P12 group exclusively to high IPP. The P20 group was both the experimental group and its own control. In this group, measurements were taken before pneumoperitoneum, when IPP reached 12mmHg and after IPP reached 20mmHg.

We used propofol, rocuronium, sevoflurane and sufentanil for anaesthesia because they maintain stable cardiopulmonary parameters, provide quick access to the airways and reduce postoperative incidence of nausea, vomiting and algesia.[25-31]

The initial ventilation parameters were constant flux, a 60% fraction of inspired oxygen, final exhaled positive pressure of 4cmH_2O, flow volume of 7mL/kg, respiratory rate of 15 breaths per minute, inspiration/expiration ratio of 1:2 and cycling to volume with the intention of promoting a volume per minute adequate to compensate for the exposure of the patient to increased IPP with CO^2. [32]

The Allen's test, performed before catheterization of the radial artery, does not fully prevent the occurrence of injury after intervention in this vessel [33-36]. In the present study, it was performed in 69 patients with no procedure-related complications.

The laparoscopic procedures using pneumoperitoneum with CO_2 are associated with risk of hypercapnia due to the increase in IPP and absorption of CO_2 by the peritoneum,[15-17] which can lead to respiratory acidosis. The CO_2 absorption depends on IPP and the integrity of the serous peritoneum. In this study, there were no statistically significant changes in $PaCO_2$ in either group. As the ventilation parameters did not change throughout the study, the data suggest that there is no increase in CO_2 absorption by the peritoneum as a consequence of the increase in IPP from 12mmHg to 20mmHg over five minutes in the presence of consistent ventilation. This may be the case because the increase in intra-abdominal pressure could cause compression of capillaries, which limits the absorption of $CO_2$1[8-20] and reduces blood flow to the splanchnic region. In these circumstances, metabolic acidosis may be associated with respiratory alkalosis.

Another study, using IPP from 1214mmHg to 14mmHg showed the unreliability of the relationship of arterial and end-tidal CO_2 after 270 minutes of procedure [23].

In conclusion, capnometry can be reliably used to monitor patients during transient increases in pneumoperitoneum pressure for introduction of the first trocar into the abdominal cavity by closed entry.

No external funding and no competing interests declared

REFERENCES

1. Buunen M, Gholghesaei R, Veldkamp R, Meijer DW, Bonjer HJ, Bouvy ND. Stress response to laparoscopic surgery: a review. *Surg Endosc.* 2004; **18**: 1022-8

2. Roll S, Azevedo JLMC, Gorski W, Abdalla R. Two-port technique of laparoscopic cholecystectomy using a microendoscope. *Endoscopy* 1997; **29**: 43

3. Grace PA, Quereshi A, Coleman J, *et al*. Reduced postoperative hospitalization after laparoscopic cholecystectomy. *Br J Surg.* 1991; **78**: 160-2

4. Böhm B, Milson JW, Fazio VW. Postoperative intestinal motility following conventional and laparoscopic intestinal surgery. *Arch Surg.* 1995; **130**: 415-9

5. Barbalho-Moulim MC, Miguel GPS, Forti EMP, César MC, Azevedo JLMC, Costa D.Silicone-ring Roux-en-Y gastric bypass in the treatment of obesity: effects of laparoscopic *versus* laparotomic surgery on respiration. *Obes Surg.* 2009. DOI: 10.1007/s11695-009-9823-9

6. Novitsky YW, Litwin DEM, Callery MP. The net immunologic advantage of laparoscopic surgery. *Surg Endosc.* 2004; **18**: 1411-9

7. Barros CJM, Sobrinho JA, Rapoport A, Novo NF, Azevedo JLMC, Sorbello A. J. *Laparoendosc Adv Surg Techn.* 2009; **19**: 345-9.

8. Sorbello AA, Azevedo JLMC, Osaka JT, Damy S, Mattosinho-França L, Tolosa EC. Protective effect of carbon dioxide against bacterial peritonitis induced in rats. *Surg Endosc.* 2010; **24**: 1849-53.

9. Neudecker J, Sauerland S, Neugebauer E, *et al*. The European Association for Endoscopic Surgery clinical practice guideline on the pneumoperitoneum for laparoscopic surgery. *Surg Endosc* 2002; **16**: 1121-43

10. Molloy D, Kaloo PD, Cooper M, Nguyen TV. Laparoscopic entry: a literature review and analysis of techniques and complications of primary port entry. *Aust N Z J Obstet Gynaecol.* 2002; **42**: 246-53

11. Bridgewater FH, Mouton WG. Rationale and intended use for the Veress needle: atranslation of the original descriptive article. *Surg Laparosc Endosc.* 1999; **9**: 241-4

12. Azevedo JLMC, Azevedo OC, Sorbello AA et al. Intraperitoneal pressure and volume of gas injected as effective parameters of the correct position of the Veress needle during creation of pneumoperitoneum. *J Laparoendosc Adv Surgl Techn*. 2009; **19:** 731-4

13. Azevedo JLMC, Azevedo OC, Miyahira SA et al. Injuries caused by Veress needle insertion for creation of pneumoperitoneum: a systematic literature review. *Surg Endosc*. 2009; **23**: 1428-32

14. Hypólito OHM, Azevedo JLMC, Caldeira FMSLA et al. Creation of pneumoperitoneum: noninvasive monitoring of clinical effects of elevated intraperitoneal pressure for the insertion of the first trocar. *Surg Endosc.* 2010; **24:** 1663-9

15 Gándara V, Vega de DS, Escriú A, Garcia Zorrilla I. Acid–base balance alterations in laparoscopic cholecystectomy. *Surg Endosc.* 1997; **11**: 707-10

16 Iwasaka H, Miyakawa H, Yamamoto H. Respiratory mechanics and arterial blood gases during and after laparoscopic cholecystectomy. *Can J Anaesth.* 1996; **43**: 129-33

17 Pearce DJ. Respiratory acidosis and subcutaneous emphysema during laparoscopic cholecystectomy. *Can J Anaesth.* 1994; **41**: 314-6

18 Ishizaki Y, Bandai Y, Shimomura K, Abe H, Ohtomo Y, Idezuki Y. Changes in splanchnic blood flow and cardiovascular effects following peritoneal insufflation of carbon dioxide. *Surg Endosc.* 1993; **7**: 420–3

19 Lister DV, Rudston-Brown B, Wriner B. Carbon dioxide absorption is not linearly related to intraperitoneal carbon dioxide insufflation pressure in pigs. *Anesthesiology* 1994; **80**: 129-36

20 Mullet CE, Viale JP, Sagnard PE. Pulmonary CO2 elimination during surgicalprocedures using intra or extraperitoneal CO2 insufflation. *Anesth Analg.* 1993; **76**: 622-6

21 Amaral JLG, Ferreira ACP, Ferez D, Geretto P. Monitorização da respiração:oximetria e capnografia. *Rev Bras Anestesiol.* 1992; **42**: 51-8

22 Wittgen CM, Andrus CH, Fitzgerald SD. Analysis of the hemodynamic and ventilatory effects of laparoscopic cholecystectomy. *Arch Surg.* 1991; **126**: 997-1000

23 Klopfenstein CE, Schiffer E, Pastor CM. Laparoscopic colon surgery: unreliability of end-tidal CO2 monitoring. *Acta Anaesthesiol Scand.* 2008; **52**: 700-7

24. Asif M, Sarkar PK. Three-digit Allen's test. *Ann Thorac Surg.* 2007; **84**: 686-7

25. Filipovic M, Michaux I, Wang J, Hunziker P, Skarvan K, Seeberger M. Effects ofsevoflurane and propofol on left ventricular diastolic function in patients with preexisting diastolic dysfunction. *Br J Anaesth.* 2007; **98**: 12-8

26 Filipovic M, Wang J, Michaux I, Hunziker P, Skarvan K, Seeberger MD. Effects ofhalothane, sevoflurane and propofol on left ventricular diastolic function in humans during spontaneous and mechanical ventilation. *Br J Anaesth.* 2005; **94**: 186–92

27 Burburan SM, Xisto DG, Rocco PR. Anaesthetic management in asthma. *Minerva Anestesiol.* 2007; **73**: 357–65

28 Dobson AP, McCluskey A, Meakin G, *et al*. Effective time to satisfactory intubationconditions after administration of rocuronium in adults. Comparison of propofol and thiopentone for rapid sequence induction of anaesthesia. *Anaesthesia* 1999; **54**: 172-97

29 Munhoz DC, Braga AFA, Potério GMB. Influence of propofol and and etomidateon rocuronium-induced neuromuscular block. Evaluation with acceleromyography. *Rev Bras Anestesiol.* 2002; **52**: 673-80

30 Dershwitz M, Michałowski P, Chang Y, Rosow CE, Conlay LA. Postoperative nausea and vomiting after total intravenous anesthesia with propofol and remifentanil or alfentanil: how important is the opioid? *J Clin Anesth.* 2002; **14**: 275–8

31 Thomson IR, Harding G, Hudson RJ. A comparison of fentanyl and sufentanil in patients undergoing coronary artery bypass graft surgery. *J Cardiothorac Vasc Anesth.* 2000; **14**: 652-6

32. Kaba A, Joris J. Anaesthesia for laparoscopic surgery. *Curr Anaesth Crit Care.* 2001; **12**: 159-65

33 Kohonen M, Teerenhovi O, Terho T, Laurikka J, Tarkka M. Is the Allen test reliable enough? *Eur J Cardiothorac Surg.* 2007; **32**: 902-5

34 Hosokawa K, Hata Y, Yano K, Matsuka K, Ito O, Ogli K. Results of the Allen test in 2940 arms. *Ann Plast Surg.* 1990; **24**: 149-51

35 Barner HB. Allen's test. *Ann Thorac Surg.* 2008; **85**: 690

36 Meharwal ZS, Trehan N. Functional status of the hand after radial artery harvesting: results in 3977 cases. *Ann Thorac Surg.* 2001; **72**: 1557-61

Tables

Table 1 - Correlation between the concentration of exhaled carbon dioxide ($EtCO_2$) and partial pressure of arterial carbon dioxide ($PaCO_2$) in the P12 group (maximum IPP of 12 mm Hg)

Correlation between $EtCO_2$ and $PaCO_2$ by time point	M0	M1	M2	M2
R	0.59	0.74	0.61	0.76
P-value	**0.0005**	**0.0000**	**0.0003**	**0.0000**
n	30	30	30	30

R = Spearman correlation coefficient; n = sample size
M0 - before pneumoperitoneum
M1 – when IPP reached 12 mm Hg
M2 - 5 minutes after IPP reached 12 mm Hg
M3 - 10 minutes after IPP reached 12 mm Hg
There was a significant correlation between $EtCO_2$ and $PaCO_2$ at each time point tested.

Table 2 - Correlation between the concentration of exhaled carbon dioxide ($EtCO_2$) and partial pressure of arterial carbon dioxide ($PaCO_2$) in the P20 group (maximum IPP of 20 mm Hg)

Correlation between $EtCO_2$ and $PaCO_2$ by time point	M0	M1	M2	M3
R	0.63	0.51	0.63	0.62
P-value	**0.0000**	**0.0012**	**0.0000**	**0.0000**
n	37	37	37	37

R = Spearman correlation coefficient; n = sample size
M0 - before pneumoperitoneum
M1 - after IPP reached 12 mm Hg
M2 - 5 minutes after IPP reached 20 mm Hg
M3 - after IPP returned to 12 mm Hg, 10 minutes after M1
There was a significant correlation between $EtCO_2$ and $PaCO_2$ at each time point tested.

FIGURES

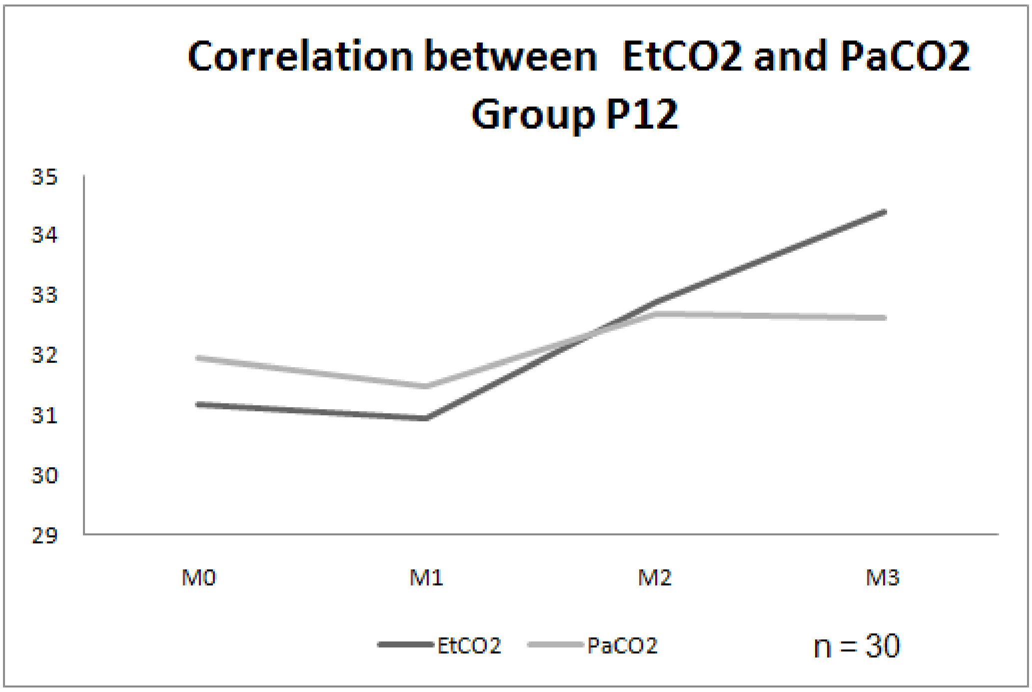

Figure 1 - Correlation between the concentration of exhaled carbon dioxide ($EtCO_2$) and partial pressure of arterial carbon dioxide ($PaCO_2$) for the P12 group (IPP of 12 mm Hg) at M0 (before pneumoperitoneum), M1 (when IPP reached 12 mm Hg), M2 (5 minutes after IPP reached 12 mm Hg) and M3 (10 minutes after IPP reached 12 mm Hg).

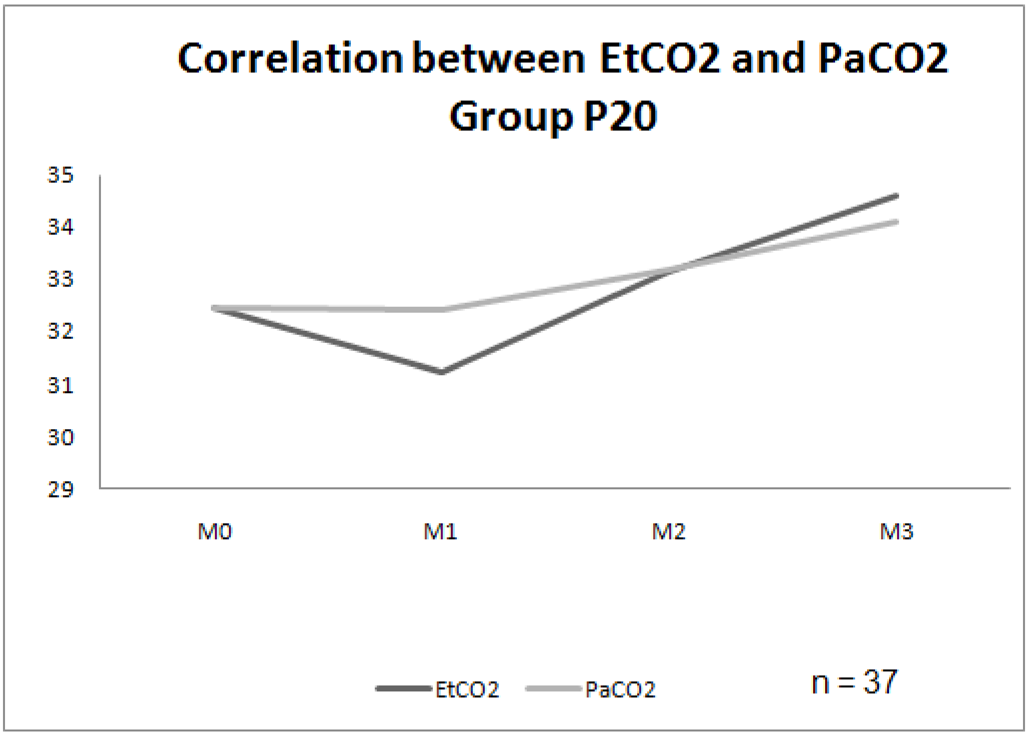

Figure 2 - Correlation between the final concentration of exhaled carbon dioxide ($EtCO_2$) and partial pressure of arterial carbon dioxide ($PaCO_2$) for the P20 group (IPP of 20 mm Hg), at M0 (before pneumoperitoneum), M1 (when IPP reached 12 mm Hg), M2 (5 minutes after IPP reached 20 mm Hg) and M3 (when IPP returned to 12 mm Hg, 10 minutes after M1).