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Hemodynamic And Pulmonary Changes During Laparoscopic Cholecystectomy

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Abstract

Objective: The changes in hemodynamic and cardiopulmonary parameters resulting from CO2 pneumoperitoneum (PP) and reverse Trendelenburg position (RTP) in laparoscopic cholecystectomy (LC) operations were investigated.

Material and Method: 30 subjects scheduled for LC were included in this study. The parameters measured were mean arterial pressure (MAP), heart rate (HR), peripheral oxygen saturation (SpO2), peak inspiratory pressure (PIP), end tidal carbon dioxide pressure (ETCO2), central venous pressure (CVP), cardiac output (CO), stroke volume (SV), stroke volume variation (SVV), systemic vascular resistance (SVR), oxygen delivery (DO2) by FloTrac-Vigileo system and arterial blood gases and arterial alveolar oxygen pressure ratio (PO2(a/A). The measurements were recorded before insuflation (BIS), at 5 minutes of insuflation (IS) and at 5 minutes of reverse Trendelenburg position (RTP), before desuflation (BDS) and after desuflation (ADS).

Results: MAP-IS and MAP-ADS were significantly high compared to MAP-BIS ($p<0.05$), CO-IS and values were significantly low compared to CO-BIS values, same parameters in ADS period were significantly high compared to the values of IS ($p<0.05$), SV-ADS were significantly high compared to the values of IS period ($p<0.05$), SVR-IS- SVR-RTP and SVR-BDS were significantly high from BIS values, same parameters of BDS and ADS were significantly low compared to IS values ($p<0.05$).

Conclusion: It is concluded that IAP increase resulting from CO2 insuflation was responsible for hemodynamic and cardiopulmonary changes observed with a semi-invasive monitoring system during LC but RTP was not so responsible in these changes.

INTRODUCTION

In 1980s, the implementation of LC with CO2 PP started a new area in bile stone surgeries and currently, have become the standard in the treatment of symptomatic cholelithiasis in worldwide [1].

LC has advantages of decreased postoperative pain, short stay in hospital, early return to normal physical activity and good cosmetic results, however it may have negative effects on hemodynamic and cardiopulmonary system due to IAP increase caused by PP resulting from CO2 insufflation to abdominal cavity and RTP to achieve sufficient surgical view [2,3]. Although it has been proved as safe, several clinical studies have demonstrated that PP may be harmful in cases of cardiovascular instability, hypercapnia, acidemia, gas embolism, decreased hepatic and renal flow and increased intracranial pressure [4]. The increased intraabdominal pressure may impair venous return and cardiac output, RTP improves the view of the surgical field however, venous return is decreased in anesthetized patients [2]. Invasive monitoring have been performed in healthy patients to investigate the combined effects of anesthesia, reverse Trendelenburg and peritoneal insufflation in abdominal laparoscopy, and up to 50 % decrease in cardiac index has been reported [5].

In addition, increases of abdominal pressure and volume impede diaphragmatic movement, decrease functional residual capacity and alveolar dead space. Rise in peak airway pressures and decrease in pulmonary compliance may trigger the risk of hypoxemia and hypercarbia[4,6].

In this study, the changes in cardiac and pulmonary parameters resulted as an outcome of IAP increase resulting from CO2 PP and RTP in patients undergoing LC operations were investigated with semi-invasive monitoring system using arterial pressure waveform analysis.

MATERIAL AND METHODS

This prospective study was conducted in 30 subjects (ASAI,II) who were scheduled for LC. Ethical committee approval and informed consents were obtained. Subjects who would have a problem due to an increase of IAP were not included in the study. The cases in which the operation started laparoscopically and continued with laparotomy, and subjects who needed IAP implementation over 14 mmHg were also excluded from the study.

Demographic data of the subjects were recorded. IV access was performed and crystalloid 500 mL bolus was given to all subjects, and continued as 10 ml/kg for volume replacement. Baseline MAP, HR and SpO2 (peripheral oxygen saturation) (GE Datex-Ohmeda S/5 Avance) monitoring data were recorded.

Fentanyl 10 µg.kg-1 and midazolam 0.025 mg/kg were performed for premedication and thiopental 5 mg/kg and rocuronium 0.5 mg/kg were induced, anesthesia was maintained with O2-N2O 50%-50% and sevoflurane 1-2%. Mechanical ventilation (GE Datex-Ohmeda S/5 Avance) was set to achieve 6 l/min air flow, 8ml/kg tidal volume, +5 cmH2O PEEP and 12/min respiratory rate.

ETCO2 monitoring was initiated after induction, radial artery cannulation and basilic vein catheterization (Cavafix, Certo 375 Braun 16 G) were performed and Vigileo monitor was connected with FloTrac sensor to artery line. Before insufflation MAP, HR, SpO2, PIP, PETCO2, SVP, CO, CI, SV, SVI, SVV, SVR, SVRI, DO2, DO2I measurements in supine position and PaO2, PaCO2, pH, $HCO3^{-}$, SaO2, PO2(a/A) (Radiometer ABL 725 device) values from blood gas sample were recorded. The measurements were recorded before insufflation, at 5 minutes of insufflation, and at 5 minutes of reverse Trendelenburg position, before desufflation and after desufflation .

Subjects included in the study were planned to have a maximum IAP of 14 mmHg (Endoscopy Device, Richaro-Wolf 5520-5124).

Reduction of SpO2 below 95% was considered as desaturation and increase of tidal volume was planned. Increase of ETCO2 value above 40 mmHg was considered as hypercarbia and respiratory rate was increased. The operation time was recorded also.

Statistical evaluation were performed by statistical analysis SPSS 16.0 for Windows program. Definitive statistics, two-way multivariant variance analysis and Tukey HSD multicomparative method for multiple comparisons were used as analysis methods. P<0.05 was considered as the statistically significant.

RESULTS

Age, body mass index, average operation time and gender with ASA physical status distributions of the subjects are presented in Table 1.

Table 1

Demographic data, ASA and operation lengths of subjects

MAP measurements of IS and ADS were significantly high compared to BIS values (p<0.05) (Figure 1); no significant difference were detected between measurement points in HR and CVP values (p>0.05) (Table 2).

CO and CI measurements of IS period showed a significant decrease compared to BIS values, however ADS values were significantly high compared to IS values (p<0.05) , SV and SVI values of ADS were significantly high compared to IS values (p<0.05), SVV values of ADS were found significantly high compared to BDS values (p<0.05), SVR values of IS , RTP and BDS were significantly high compared to BIS values, SVR-BDS and SVR-ADS values were found significantly low compared to SVR-IS values (p<0.05), SVRI-IS values were significantly high compared to SVRI-BIS values while SVRI-RTP, SVRI-BDS and SVRI-ADS values were significantly low compared to SVRI-IS values (p<0.05), DO2 -IS values were significantly low compared to DO2BIS values (p<0.05) and no significant difference was detected between DO2I values of the intervals (p>0.05)(Table 2, 3).

Table 2

SAP, DAP, MAP, HR, SVP, CO and CI values according to measurement times of subjects (mean+std)

Table 3

SV, SVI, SVV, SVR, SVRI, DO2 and DO2I values according to measurement times of subjects (mean+std)

SpO2 of values ADS were significantly high compared with values of BDS (p<0.05), SpO2 was not below 97% in any subject, PIP and PETCO2 values of IS, RTP, BDS and ADS were significantly high compared to BIS values, while PIP-BDS were significantly high compared with PIP-IS values, PIP-ADS values were significantly low, a significant increase was detected in PIP values of BDS and RTP compared to ADS-PIP values (p<0.05), PETCO2 was not detected above 40 mmHg in any case (Table 4).

Table 4

PIP, PETCO2, PaO2, PaCO2, pH, SaO2 and PO2(a/A) values according to measurement times of subjects (mean+std)

Significant reductions were detected in PaO2 values of RTP, BDS and ADS compared to BIS values, PaO2-IS and PaO2-BDS values were found significantly high compared to PaO2-ADS value ($p<0.05$). There was no difference between measurements of PaCO2 and HCO_3^- values ($p>0.05$), HCO_3^- values ranged between 17-29.1 mmol/l, pH values of BDS and ADS were significantly low compared to values of IS ($p<0.05$), SaO2 values of BIS, IS and RTP were found significantly high compared to ADS values ($p<0.05$), no significant difference was detected between PO2(a/A) values in any period ($p>0.05$) (Table 4).

DISCUSSION

Hemodynamic and cardiopulmonary changes occurred during LC depend on the current health status of the patient, the anesthesia technique, several surgical factors such as IAP, the absorption of CO2, the position of the patient and the length of the surgical procedure [7]. Besides these changes, the specific potential risk factors related to LC (visceral injury, difficulty in detecting the amount of blood loss) require full cardiac and respiratory monitoring of the patients.

FloTrac-Vigileo system was preferred for cardiac monitoring in our study as it is less invasive and more applicable compared to pulmonary artery catheterization and other methods for arterial pressure wave analysis. This recently developed device offers the possibility of uncalibrated continuous CO measurement based on arterial waveform analysis [8]. It is noted that in less compromised patients, Flotrac sensor requires reliable CO calculation [9].

The effect of IAP increase on cardiac functions depends on intravascular volume, level of IAP and position of the patient. In animal experiments, an increase of 5 mmHg in IAP caused an increase in CO in hypervolemic animals due to the increase of average systemic pressure and venous return; in contrast, the increase in average systemic pressure caused a decrease in CO in hypo and normovolemic animals because of the dominancy of vena cava compression [10,11]. Backlund et al. reported that iv volume replacement was important in subjects who underwent laparoscopic surgery and 10 ml/kg fluid replacement increased CO of subjects in response to CO2 insufflation [12].

Hemodynamic effects of PP depends on the status of the subjects as well as IAP level. In a study conducted by Dexter et al. in which insufflation pressures of 7 and 15 mmHg were compared in LC cases, HR and MAP increased similarly in both groups, however SV and CO significantly decreased in the high pressure group [13]. In a study conducted by Rishimani et al., while MAP was increased 41.15% with 14 mmHg and 24.94% with 6 mmHg, HR remained constant in both IAP values [14].

Subjects are usually positioned in RTP to facilitate surgical view during laparoscopy however, these positional changes may effect hemodynamic functions. Berg et al. conducted a study in LC cases and identified that CO2 insufflation resulted in increases of 21% in MAP, 12% in HR and over 200% in CVP in supine position, and with RTP, they detected increases of 28% in MAP, 18% in HR [15].

In a study of Hirnoven et al. significant reduction in pulmonary artery and pulmonary capillary wedge pressure (PCWP), CVP, CO, CI and SV, SVI in supine position and significant increases in SVR and SVRI in RTP were detected in awake subjects. In patients under anesthesia, similar effects were observed with increases in HR in RTP. Compared to BIS values of supine position, significant increases in HR, CVP, pulmonary artery pressure, PCWP, SVR and SVRI, and decreases in CI and SVI were detected with PP (IAP 13-16 mmHg) and RTP. As a result, Hirnoven et al. proved that RTP alone highly affected the venous return without an IAP increase and caused an increase in SVR and a decrease in other hemodynamic parameters [2].

In a similar study by Joris et al., MAP and CI were significantly decreased with anesthesia induction, a decrease of 17% in MAP and 14% in CI due to the decrease in cardiac preload was detected with RTP and insufflation pressure of 14 mmHg resulted with an increase in HR, CVP, MAP by 37%, in SVR by %65, in pulmonary vascular resistance up to 90% and an apparent decrease in CI up to 50% in RTP. In the same study, it was suggested that increased SVR and PCWP were accompanied with increased MAP as a result of CO2 PP [5].

Another study by Joris et al. showed that while minimum reduction in MAP and an apparent reduction in CO were seen after induction of anesthesia, an apparent reduction in PCWP occurred with changing into RTP followed by a further decrease in CO and MAP, more reduction in CO at 5 min of insufflation, right atrial pressure and MAP increased. An evident increase was detected in SVR, pulmonary vascular resistance (PVR) and PCWP. All hemodynamic parameters returned to preoperative values in ADS period. Moreover, it was proved that a sudden increase was seen in vasopressin level at 5 min of insufflation while epinephrine, norepinephrine, renin and cortisol levels increased during laparoscopy and it was suggested that the changes in MAP and SVR occurred with the effect of neurohumoral factors as well as the mechanical effect of the IAP increase. Joris et al. detected decrease of DO2 parallel to the significant decreases in CO in the same study [16].

In the current study increases in MAP, SVR and SVRI values along with decreases in CO, CI, SV, SVI, DO2 and DO2I values were seen without any changes in HR, CVP and SVV values with insufflation. Although arterial pressures increased, the detected decrease in cardiac parameters suggested that preloading with crystalloid preoperatively did not achieve adequate hydration. Unlike several studies, subjects positioned into RTP did not present prominent hemodynamic changes; no significant decrease occurred in MAP values; HR, SVP, SV, SVI and SVV values remained stable; CO, CI, DO2 and DO2I values showed mild increases while SVR and SVRI values moderately decreased. BDS values were similar with RTP. With the discontinuation of CO2 insufflation the values of CO, CI, SVR, SVRI DO2 and DO2I returned to baseline values, and DAP and MAP increased, SV and SVI reached the highest levels during the study period. These changes observed in ADS period are related to hyperdynamic circulation resulting from cease of partial compression on large abdominal veins. The increases and decreases in DO2 value were parallel to CO and CI. Elevated CO2 directly caused myocardial depression and vasodilation. In addition to it sympathetic stimulation caused tachycardia and systemic vasoconstriction.

The effect of IAP increase on pulmonary functions depends on abdominal expansion and movement of diaphragm cephalad, that is related to the level of insufflation pressure; thus intrathoracic pressure is increased, pulmonary basal segments are subjected to compression and expansion of the lungs is restricted. Pulmonary compliance is decreased by up to 50% and peak inspiratory pressures are increased, vital capacity is decreased, however these pathophysiological changes return to normal values with desufflation [3, 17].

Volpino et al. did not detect changes in systemic blood pressure and HR during PP and RTP in their cases. No changes were observed in SaO2 and PaO2 values, however peak air way pressure and PETCO2 increased without statistically significance, pulmonary compliance decreased, pH also decreased significantly and significant increases were detected in PaCO2 and PO2(A-a) [18].

In a study by Rishimani et al., airway pressure and ETCO2 have increased by 44.73% and 20.5% respectively, with 14 mmHg IAP and 10.2% and 10.6% respectively, with 6 mmHg IAP, and no change has occurred in SaO2 with both IAP. ETCO2 has increased 50% less with IAP of 6 mmHg compared with IAP of 14 mmHg without any change in ventilation modes [14].

Galizia et al. have detected an increase up to 109% in PIP after 12 mmHg CO2 PP, increases in PETCO2 and higher increases in PaCO2 compared to ETCO2, and a mild decrease in pH due to the increase of PaCO2. They have not changed the modes of mechanical ventilation to compensate these changes and minute ventilation was maintained constant. All parameters have returned to normal values after desuflation [4].

In a study conducted by Ishikawa et al. for investigation the pulmonary effects of LC, PaCO2 presented a sudden increase in the first 10 minutes after insufflation compared to BIS values without any difference in blood pressure and heart rate and this increase continued gradually, PaCO2 have reached high values at 40 and 80 minutes of insufflation (40.4 and 42.7 mmHg), ETCO2 have started to increase in the first 10 minutes and reached significant values after 20 minutes, and PaO2 was stable during PP. They have found that PO2(A-a) decreased gradually from the first 5 minutes following insufflation and PIP has increased gradually but no significant difference were present compared to BIS [6].

Berg et al. have detected 16% increase in ventilation pressures and 18% decrease in PaO2 values after CO2 insuflation. An increase of 2.4 mmHg in PETCO2 was seen with CO2 insufflation in supine position and this increase reached up to 5 mmHg when subjects were changed into RTP. pH has decreased from 7.47 to 7.43 during PP while PaCO2 has increased in a range of 5.1-38.7 mmHg and continued increasing up to 43.9 mmHg after desufflation [15].

In the present study, no change in PaCO2 and pH values were recorded in the measurement periods. PIP increased rapidly due to the increase in intrathoracic pressure and a decrease in pulmonary compliance with CO2 insuflation. An increase in ETCO2 and a decrease in PaO2 and PO2(a/A) values were detected with the reduction in vital capacity and functional residual capacity. However no significant change was detected in SpO2, pH, $HCO3^-$ and SaO2. In subjects changed into RTP, PIP and ETCO2 values continued to increase and PaO2 to decrease. PIP was decreased due to the reduction of intrathoracic pressure during ADS while ETCO2 levels were still high. Insufflation have increased the delivery of CO2 to the lungs which is especially important in patients particularly at risk of decreased pulmonary function. And these group of patients must be strictly monitored. The observed increments in ETCO2 in normal ranges and the reason for PaCO2 and pH values to remain constant in measurement points might be related to the length of the surgery and physical status of the subjects in this study.

Our results maintained with FloTrac sensor confirm earlier published studies. As a result, we think that IAP increase resulting from CO2 insuflation alone was responsible for hemodynamic and pulmonary changes observed during LC, however RTP was not so effective in these changes. It is desired to avoid intraoperative cardiopulmonary abnormalities by maintaining low insufflation pressures, preoperative hydration and head up tilt as much as 10-15 degrees.

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