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Evaluation of pneumoperitoneum pressures during laparoscopic surgery on the intracranial pressure by measuring ultrasonographic optic nerve sheath diameter

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ABSTRACT

Aim: To investigate the effect of CO2 pneumoperitoneum at two different pressures (10 mmHg and 15 mmHg) on intracranial pressure (ICP) in ASA I-II-III risk patients undergoing laparoscopic cholecystectomy under general anesthesia by measuring changes in optic nerve sheath diameter (ONSD) with ocular ultrasonography**.**

Methods: Forty patients between the ages of 18-65, who underwent laparoscopic cholecystectomy under general anesthesia and at risk of ASA I-II-III, were included the study. Patients in group low-pressure CO2 pneumoperitoneum (Group LP) were scheduled to receive CO2 pneumoperitoneum with a pressure of 10 mmHg, and patients in group high-pressure CO2 pneumoperitoneum (Group HP) with a pressure of 15 mmHg. Optical nerve sheath diameter measurements were performed different times each groups and the obtained values were evaluated statistically.

Results: There was not any significant difference between the groups in terms of age, gender, height, weight, duration of intubation, duration of anesthesia and pneumoperitoneum, using opioids and intravenous fluid. Group LP showed significant lower ocular ultrasound measurement of OSND compared Group HP within the T2 and T3 period (p=0.001).

Conclusions: ONSD is an important indicator of the effect of increased intraabdominal pressure on ONSD and hence ICP. We found that performing low pressure, produces a lesser increase in ONSD, and we think that this will have less impact on ICP.

Keywords: Optic nerve sheath diameter, laparoscopic surgery, intracranial pressure, pneumoperitoneum.

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1. Introduction

Laparoscopic surgery is a more powerful alternative to conventional open surgery because of its minimally invasive approach and less tissue trauma. In addition, decreasing the incidence of postoperative pain and hemorrhage, and early mobilization of the patient; shortening the length of hospitalization that leads to minimalize postoperative morbidity and mortality, are important advantages [1-3]. However, at technical standpoint in order to improve the surgeon's field of view, carbon dioxide insufflation between the peritoneal leaves is required, that should be limited to a pressure of

10-15 mmHg. This leads to changes in respiratory and cerebrovascular physiology [4, 5].

Carbon dioxide insufflation for laparoscopic surgery, causes an increase in intraabdominal pressure and lifts the diaphragm. This leads to increased thoracic pressure, resulting in compression of the inferior vena cava and increased central venous pressure. It has been reported in the literature that this situation increases intracranial pressure (ICP) by increasing cerebral spinal fluid pressure [6, 7]. It is also known that many physiological side effects such as decreased venous turnover, hypercapnia and respiratory acidosis increase ICP [6-8].

Intracranial pressure ≥20mmHg, is called intracranial hypertension. The gold standard for the measurement of ICP is intraventricular and intraparenchymal devices [9, 10]. However, these invasive techniques are not suitable for practical use because of the risk of serious complications such as increased risk of infection and bleeding [10]. On the other hand, ocular ultrasound measurement of optic nerve sheath diameter (ONSD) is a noninvasive method that has been reported to be reliable and accurate compared to invasive techniques used to determine ICP increase [9-11].

In the literature, the normal value of the optic nerve sheath diameter should be less than 4.5 mm in a healthy person and if the ONSD is more than 5 mm, it reflects over 20 mmHg ICP [9, 12].

Although laparoscopic surgery has been reported to increase ICP in the literature, there are few studies evaluating the effect of different pneumoperitoneum pressures on intracranial pressure by ultrasonographic optic nerve sheath diameter measurement.

The aim of this study was to investigate the effect of CO2 pneumoperitoneum at two different pressures (10 mmHg and 15 mmHg) on intracranial pressure (ICP) in ASA I-II-III risk patients undergoing laparoscopic cholecystectomy under general anesthesia by measuring changes in optic nerve sheath diameter (ONSD) with ocular ultrasonography.

2. Materials and methods

For this randomized, controlled study, the approval of the Bolu Abant İzzet Baysal University Clinical Research Ethics Committee was obtained (2018/232). Forty patients between the ages of 18-65, who underwent laparoscopic cholecystectomy under general anesthesia and at risk of ASA I-II-III, were included the study.

People with known eye disease (diabetic retinopathy, glaucoma, retinal detachment), history of eye surgery, history of chronic obstructive pulmonary disease, history of elevated ICP (pseudotumor cerebri, hydrocephalus or venticuloperitoneal shunt), congestive heart failure, intubation time over 30 seconds and BMI>30 kg/m2 were excluded from the study. Written informed consent was obtained from the patients before the study. The patients included in the study were divided into 2 randomized groups of 20 people in each.

Patients in the low-pressure CO2 pneumoperitoneum (Group LP) group received 10 mmHg CO2 pneumoperitoneum, and patients in the high-pressure CO2 pneumoperitoneum (Group HP) group received 15 mmHg CO2 pneumoperitoneum.

The patients were taken to the operating room without premedication. Vascular access was made with 18G catheter. All patients underwent ECG monitoring for heart rate, pulse oximetry (SpO2) for peripheral oxygen saturation, and blood pressure cuff for noninvasive blood pressure (NIBP) monitoring. Anesthesia induction was started with 2mg/kg propofol and 2mcg/kg fentanyl. After unconsciousness, muscle relaxation was achieved with 0.6 mg/kg rocuronium and intubated with tracheal tube (7-7.5) after 3 minutes of ventilation with a mask. Mechanical ventilation was provided with a tidal volume of 8-10ml/kg and end-tidal CO_2 (etCO_2) values between 35 and 40 mmHg. Anesthesia was maintained using 1–1.5 minimum alveolar concentration (MAC) of desflurane in a 50%/50% oxygen/air mixture while monitoring the end-tidal desflurane concentration. CO_2 pneumoperitoneum was applied by using intra-abdominal pressure (IAP) of 10 mmHg in Group LP and 15 mmHg in Group HP. Ocular ultrasound was performed by two researchers with same experience. Optical nerve sheath diameter measurements were performed in supine position before general anesthesia (T0), in supine position 10 minutes after induction (T1), in reverse trendelenburg position 10 minutes after CO_2 pneumoperitoneum (T2), in reverse trendelenburg position 30 minutes after CO_2 pneumoperitoneum (T3). Also it was performed after CO_2 pneumoperitoneum termination in supine position (T4). All the results recorded.

Optical nerve imaging was performed with Sonosite Brand Plus 180 ultrasound and high frequency (>7,5 MHz) linear transducer that are used in our clinic for daily routine. The optic nerve sheath diameter was measured via transducer placing the patient in the supine position and the eyelids closed, with the aid of gel on the eyelid without applying high pressure. The optic nerve sheath diameter was measured on the transverse and sagittal planes, 3mm behind the optic disc for both eyes and the mean of four values obtained. Heart rate (HR), SpO_2, mean arterial pressure (MAP), etCO_2 and airway pressures Ppeak and Pplato of the patient were recorded simultaneously with optic nerve sheath diameter measurement.

2.1. Statistical Analysis: Gender distributions between groups were statistically evaluated by chi-square test. The distributions of variables were evaluated by Kolmogorov-Simirnov test. The homogeneous distributions were evaluated by Independent Slim test and the non-homogeneous distributions were evaluated by Mann-Whitney U test. A repeated measures two-way ANOVA was conducted to see the effect of time and study group on ONSD. For multiple comparisons post-hoc Bonferroni's test was used. Significance was set at $p<0.05$ and the analyses were performed using the Statistical Package for Social Sciences 25.0 for Windows (SPSS Inc., Chicago, Illinois, USA).

3. Results

There was not any significant difference between the groups in terms of age, gender, height, weight, duration of intubation, duration of anesthesia and pneumoperitoneum, using opioids and intravenous(iv) fluid ($p>0.05$) (Table 1).

There was no statistically significant difference between the groups in terms of MAP, HR, SpO_2 in all time points ($p>0.05$ for all) (Table 2). There was also no statistically significant, difference in terms of the EtCO_2, Ppeak, Pplato ($p>0.05$) (Table 3).

Group LP showed significant lower OSND compared Group HP within the T2 and T3 period ($p=0.001$) (Table 4) (Figure 1). Mean OSND (mm) was 5.2±0.4 in T2 period and 5.4±0.3 in T3, and 5.5±0.3 and 5.8±0.4 in Group 2, respectively.

Results expressed as the mean ± standard deviation or number (%), T0: In supine position before general anesthesia; T1: In supine position 10 minutes after induction; T2: In reverse trandelenburg position 10 minutes after CO_2 pneumoperitoneum; T3: In reverse trandelenburg position 30 minutes after CO_2 pneumoperitoneum; T4: It was performed after CO_2 pneumoperitoneum termination in supine position.

Table 1. Demographics and clinical characteristics of the patients.

Parameters	**Group LP (low-pressure CO_2 pneumoperitoneum)**	**Group HP (high-pressure CO2 pneumoperitoneum)**	***P* value**
Number of patients (*n*)	20	20	
Age (yr)	46.8±12.6	52.5±12.4	0.155
Gender			0.591
Male	12 (%60.0)	13 (%65.0)	
Female	8 (%40.0)	7 (%35.0)	
Weight (kg)	77.2±11.2	86.3±24.5	0.164
Height (cm)	169.5±8.3	164.8±20.7	0.368
ASA status I/II	15/5	17/3	0.140
Duration of Pneumoperitoneum (min)	43.5±16	46±21	0.086
Duration of anaesthesia (min)	67.5±21	72±25	0.693
Duration of Laryngoscopy (sec)	16.3±5.8	15.4±4.9	0.620
Fentanyl consumption (ug)	108.7±27.2	107.5±24.5	0.879
Crystalloid intake (ml)	925±240	987±343	0.509

Values are expressed as mean (SD) or n (%).

Table 2. Hemodynamic data.

Groups		T0	T1	T2	T3	T4
Group LP (10mmHg)	HR (beats/min)	86.7±15	85.7±11	86.5±14.5	77.1±13.8	75.3± 11.8
	MAP (mmHg)	109±14	92±17	106±12	106±12	104±15
	$EtCO_2$	98.1±1.8	99.1±1.1	98.7±1.2	98.5±1.5	98.9± 1.5
Group HP (15mmHg)	HR (beats/min)	86±13.7	83.6±13.4	82.5±11.8	81.4±12.2	77.7±10.3
	MAP (mmHg)	114±19	92±13	107±15	107±11	102±14
	$EtCO_2$	97.2±2.4	98.7±1.4	98±2	97.5±2.1	99±1.6

Table 3. Respiratory parameters at each time point.

Groups		T0	T1	T2	T3	T4
Group LP (10mmHg)	Peak inspiratory pressure (cm H2O)		15.8±2.8	19.7±3.1	20±3.8	17.4 ±2.5
	Plateau pressure (cm H2O)		15±2.8	18±3	18.5±4	16±2.5
	ETCO2 (kPa)		35.5±1	37.5±1.7	37.5±2	36.7±1.6
Group HP (15mmHg)	Peak inspiratory pressure (cm H2O)		18±4.4	22±3.1	23±4.1	18.7±3.5
	Plateau pressure (cm H2O)		16.8±3	20±4	21±4.5	17±3
	ETCO2 (kPa)		35.5±1	37.5±2.5	38±2.3	37±1.8

Table 4. Changes in optic nerve sheath diameter (ONSD) values.

Time	ONSD (mm)		*P* value
	Group LP (10mmHg)	Group HP (15mmHg)	
T0	4.3±0.2	4.3±0.2	0.681
T1	4.6±0.5	4.5±0.4	0.770
T2	5.2±0.4 [a]	5.5±0.3	0.025
T3	5.4±0.3 [a]	5.8±0.4	0.004
T4	4.7±0.3	4.8±0.4	0.194

Results expressed as the mean ± standard deviation or number (%), T0, before induction T1, Immediately after insertion of the mouth gag T2, just before removal of the mouth gag T3, just before extubation. a : showed significant differences in changes in ONSD of Group LP and Group HP

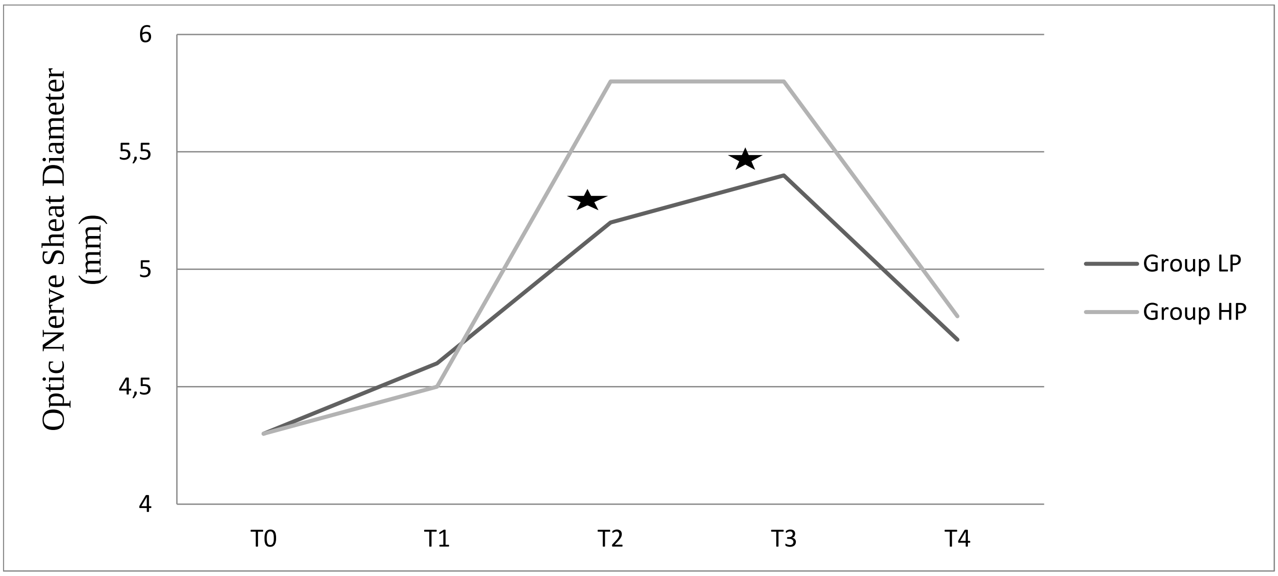

Figure 1. Changes in optic nerve sheath diameter (ONSD) values.

Values are expressed as mean (SD). T0, before induction T1, Immediately after insertion of the mouth gag T2, just before removal of the mouth gag T3, just before extubation. ★ : Significantly different when compared between of Group LP and Group HP ($p<0.05$).

4. Discussion

In this study, we investigated the effect of two different pneumoperitoneum pressures (10 mmHg and 15 mmHg) on intracranial pressure by looking at ultrasound-guided OSND. We found that pneumoperitoneum caused an increase in ONSD that did not return to baseline despite termination of pneumoperitoneum. The highest ONSD level was observed after 30 minutes of pneumoperitoneum applied. However, there were significant time-related differences in measured by ultrasonography after 10 minutes and 30 minutes were also less elevated than in patient who underwent 15mmHg pneumoperitoneum.

Optic nerve surrounded by subarachnoid space and duramater. So it has connection with intracranial subaracnoid space. It has been reported that the changes in intracranial pressure will affect ONSD via cerebrospinal fluid that leads to this area [13].

Many studies in the literature have shown that ultrasonographic measurement of ONSD is a useful and noninvasive method for the detection of ICP [14-18]. It has also been reported that ONSD, measured by ultsonography, strongly correlates with ICP measured by invasive methods, and is an accurate, simple and rapid method for detecting rapid changes in ICP [19-21]. We observed the immediate changes before and after the operation who underwent pneumoperitoneum by measuring ultrasonographic ONSD. As mentioned in the literature, we evaluated the effect of ICP easily and noninvasively. In addition, we found that the difference in ONSD had a significantly longer effect on ICP at 15 mmHg than at 10 mmHg, 30 minutes after pneumoperitoneum was applied.

It has been shown in the literature that CO2 pneumoperitoneum increases ICP in laparoscopic surgery, this increase peaks in the period following CO2 pneumoperitoneum and decreases after desufflation [17, 18, 22, 23]. In a meta-analysis, Kim et al [18] found that ONSD values in the early period (0-30 minutes) and in the late period (30-120 minutes) after CO2 pneumoperitoneum were significantly higher than those after anesthesia induction and that these values returned after CO2 desufflation.

Halverson et al. [24] reported that direct mechanical effect of CO2 pneumoperitoneum disrupts lumbar venous plexus drainage by increasing abdominal pressure, which may increase ICP independently of other factors. In addition, it has been reported in the literature that both intraabdominal and intrathoracic effects of CO2 pneumoperitoneum increase ICP by increasing central venous pressure [6-8]. Dip et al. [6] applied 14 mmHg CO2 pneumoperitoneum in abdominal laparoscopic surgery and showed that the mean baseline ONSD increased from 4.7mm to 5.8mm at 30 minutes. In another study, they found that the mean baseline ONSD increased from 4.8mm to 5.5mm [12].

In the literature, these values are similar in patients with 15mmHg CO2 pneumoperitoneum. In our study, we observed that the mean baseline ONSD was 4.6mm and increased to 5.8mm 30 minutes after 15mmHg CO2 pneumoperitoneum and all these values were consistent with the literature.

While there are many studies in the literature with 15mmHg CO2 pneumoperitoneum in adult surgery, we have not found a study investigating changes in ONSD of 10mmHg pressure and comparing changes in ONSD of both pressures. In pediatric patients, Min JY et al. investigated the effects of 10mmHg CO2 pneumoperitoneum on ONSD and showed that ONSDs with an average baseline of 4.3mm increased to 4.6mm at 10 minutes.

In our study, we observed an average increase of 0.6 mm in ONSD in the group in which we applied 10 mmHg low pressure in our 10 minute measurement, while we observed an increase of 1mm in the group in which we applied 15 mmHg pressure. This is an important indicator of the effect of increased intraabdominal pressure on ONSD and hence ICP. We found that performing low pressure, produces a lesser increase in ONSD, and we think that this will have less impact on ICP.

4.1. Conclusion

As a result, 15mmHg CO2 pneumoperitoneum resulted in a higher increase in ONSD measured by ultrasound, than those applied 10mmHg. However, considering the increase in ONSD, even 10mmHg CO2 pneumoperitoneum may increase ICP. Therefore, although this pressure increase is probably insignificant in healthy people, 10mmHg insufflation pressure should be used in patients with intracranial pathology or at increased risk of ICP and attention should be paid to increased intracranial pressure.

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Ethical Statement: *This clinical research approved by Bolu Abant Izzet Baysal University Clinical Researches Ethics Committee in 17/12/2018 with 361 number.*

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