The assessment of the effect of different intraabdominal pressures used for laparoscopic cholecystectomy surgery on optic nerve sheath diameter: a prospective observational cohort study

Abstract

Background/Aim: During laparoscopic cholecystectomy operations, increases in intra-abdominal, intra-thoracic and intracranial pressures (ICP) can be seen after pneumoperitoneum created for surgical imaging. Orbital ultrasonography (USG), which has been developed in recent years, is a method that can evaluate the ICP by measuring the optic nerve sheath diameter (ONSD) from the eyeball.

In our study, we aimed to evaluate whether different intraabdominal pressure values created during laparoscopic cholecystectomy operations correlate with ICP by measuring ONSD.

Materials and Methods: The study included a total of 90 patients with American Society of Anesthesiologists (ASA) physical status classification I (ASA I) and II (ASA II) and ages from 18-65 years with laparoscopic cholecystectomy planned.

After patients were intubated, in the 5th minute bilateral ONSD measurements were performed. The same measurements were performed in the 15th and 30th minutes after CO₂ insufflation and additionally 10 minutes after CO₂ was released at the end of the operation. During intrabdominal CO₂ insufflation patients with 10 mmHg pressure applied comprised Group 1, patients with 12 mmHg pressure applied were Group 2 and patients with 14 mmHg pressure applied comprised Group 3.

Results: The study was completed with 89 patients, 51 female and 38 males. One patient was excluded from the study due to erroneous values.

The variations in ONSD measured in the right-left eye before pneumoperitoneum and in the 15th and 30th minutes after abdominal CO₂ insufflation were observed to be
statistically significant \( (p<0.01) \). In all three groups, the right and left eye ONSD values were not identified to be statistically significantly different \( (p>0.01) \).

A significant increase was observed in ONSD values in direct proportion to the increase in intraabdominal pressure in patients undergoing laparoscopic cholecystectomy surgery.

**Conclusion:** USG guided ONSD measurements appear be a guide to ensure optimization of intraabdominal pressures and safe anesthesia administration for patients, especially those at risk of ICP increase, during laparoscopic surgery.

**Key words:** Optical nerve sheath diameter, intracranial pressure, laparoscopic cholecystectomy, ultrasonography

1. **Introduction:**

   With the introduction of laparoscopic surgery, laparoscopic cholecystectomy has entered practice as the gold standard for gallstone and gallbladder diseases [1]. Laparoscopic cholecystectomy is a minimally invasive surgical procedure to remove the gallbladder and became the preferred technique over open cholecystectomy at the beginning of the 1990s [2]. The laparoscopic cholecystectomy method is used for indications like cholecystitis (acute/chronic), symptomatic cholelithiasis, bile dyskinesia, acalculous cholecystitis, gallstone pancreatitis and gallbladder masses or polyp treatment [3].

   During laparoscopy, a range of respiratory, hemodynamic and metabolic changes occur linked to pneumoperitoneum and patient position. These changes make anesthesia administration complicated [4]. After \( \text{CO}_2 \) insufflation, increases may be observed in intraabdominal, intrathoracic and intracranial pressures (ICP). Though most of these can
be monitored with advanced monitoring techniques, these monitoring systems are insufficient to observe changes in the intracranial cavity.

To measure ICP, many techniques like transcranial Doppler, B-mode transcranial sonography and orbital sonography have been developed. Orbital ultrasonography (USG) is a method developed in recent years that can evaluate ICP with optic nerve sheath diameter (ONSD) measurement through the eyeball which requires support by studies. Ultrasonographic measurement of ONSD as a noninvasive, simple and rapid way to detect pressure changes of the intracranial compartment. A series of studies have been accomplished comparing the ultrasonographic measurement of the ONSD with neuroimaging in adults [5-9]. In one study, the ONSD / ICP correlation was found to be 0.685 (95% CI 0.626-0.737) [10]. In a study in children, sixty-four patients were recruited, of whom 24 (37%) had a confirmed diagnosis of increased ICP. The sensitivity of ONSD as a screening test for increased ICP was 83% (95% confidence interval [CI] 0.60 to 0.94); specificity was 38% (95% CI 0.23 to 0.54); positive likelihood ratio was 1.32 (95% CI 0.97 to 1.79) and negative likelihood ratio was 0.46 (95% CI 0.18 to 1.23) [11,12]. Most of these studies have considered an upper normal ONSD limit of 5 mm. This cut-off point was proposed for patients above age 4 by the first validation studies on the ONSD and was found to have a good accuracy as a predictor of intracranial hypertension, with a sensitivity ranging from 70.8% to 100% and a specificity ranging from 63% to 100% [13,14].

In our study, we aimed to evaluate whether ICP was directly proportional to an increase in intraabdominal pressure created by CO₂ pneumoperitoneum with 10 mmHg, 12 mmHg, and 14 mmHg pressures during primary laparoscopic cholecystectomy operations. The secondary purpose of the study is to evaluate the ICP changes that may
occur due to increased abdominal pressure with USG-assisted ONSD measurement and to determine the most appropriate abdominal pressure to be applied for pneumoperitoneum in patients with increased ICP.

2. Materials and Methods

This single-center prospective observational clinical study included 90 patients with laparoscopic cholecystectomy surgery planned with general anesthesia under elective conditions in American Society of Anesthesiologists (ASA) physical status classification I (ASA I) and II (ASA II), aged from 18-65 years. Written informed consent was obtained from each patient.

Patients with ASA III and ASA IV, previous abdominal-orbital trauma or surgical history, glaucoma, without consent given by themselves or legal heirs, known intracranial space-covering lesion, with high ICP and with emergency surgery planned were not included in the study.

Preoperative evaluation noted name-surname, age, sex, date of operation, height-weight values, and ASA classification before entry into the operating room for all patients with no solid or liquid food intake for at least 6 hours. Later patients on the operating table had standard monitoring (Electrocardiogram, noninvasive arterial blood pressure, peripheral oxygen saturation and bispectral index (BIS)) followed by anesthesia induction (intravenous propofol 2 mg kg⁻¹, rocuronium 0.5 mg kg⁻¹, fentanyl 1 mcg kg⁻¹). After sufficient muscle relaxation was present, patients were intubated by the anesthesiologist and maintenance anesthesia with titration of sevoflurane, 50% O₂ – 50% air, and remifentanil infusion of 0.05-0.1 mcg kg⁻¹ min⁻¹ was planned to keep BIS values from 40-60.
In the 5th minute after intubation, bilateral ONSD was measured before intraabdominal CO₂ insufflation was completed by the surgical team with a Veress needle and the intraumbilical method. These measurements were recorded as basal values. Mechanical ventilator settings were tidal volume 8 ml kg⁻¹, frequency 13, positive end expiratory pressure (PEEP) 5 in the volume control mode and 50% oxygen-air mixture was used. End tidal carbon dioxide (Et-CO₂) was held in the interval 30-40 mmHg. Airway peak and plateau pressure values were recorded. The same measurements were made in the 15th and 30th minutes after CO₂ insufflation and 10 minutes after CO₂ was released at the end of the operation. During intrabdominal CO₂ insufflation, patients with 10 mmHg pressure were included in Group 1, patients with 12 mmHg pressure were in Group 2 and patients with 14 mmHg pressure were included in Group 3. Single and careful measurement is made for all ONSD values.

ONSD measurement was performed using USG (SonoSite M-Turbo HFL50x/15-6 MHz Lineer Transducer SonoSite, Inc. Bothell, WA 98021 USA) with the same anesthesiologist (Dr. Tuna ERTÜRK) responsible for the general surgery operating room who previously performed this measurement on 30 patients. At all-time points when ONSD was measured, heart rate (HR), mean arterial pressure (MAP), peripheral oxygen saturation (SpO₂), end tidal carbon dioxide values (Et-CO₂), respiration rate, and airway peak and plateau pressure values were recorded.

During ONSD measurement, after patients were placed on the surgical table in supine position and intubated, they were given the 15° left and 20° reverse-Trendelenburg position in which the operation would be performed. Ultrasound gel was spread on the closed eyelids and a 15-6 MHz linear probe was placed on the temporal section of the eyelid. Bilateral measurements were performed by avoiding placing excess pressure on...
the eye (Pictures 1, 2). During measurement the USG monitor was set to 4 cm depth and image in B mode. The appropriate angle was given to the probe to allow visualization of the eyeball and optic nerve on the monitor. On USG images, the ONSD was measured 3 mm below the junction site between the eyeball and optic nerve on a transverse line bilaterally and values were recorded.

At the end of surgery, patients were routinely extubated and taken to the post surgery care unit. The modified Aldrete score (MAS) was used for patient recovery and patients with score of 9-10 were transferred to the ward on trolleys.

**Statistical analysis**

After data were uploaded to a computer environment, analyses were performed with the SPSS (Statistical Package for the Social Sciences Inc., Chicago, IL, USA) 20.0 statistical program. When evaluating data, descriptive statistical methods (frequency, percentage, mean, standard deviation) were used. Conformity to normal distribution tested with Kolmogrow-Smirnow and Kurtosis-Skewness coefficients. Then continuous
variables were compared with ANOVA and post-hoc Tukey. For comparison of categoric
variables, the chi-square test was used to determine differences between groups. The
results were evaluated at the 95% confidence interval and the significance level at p
<0.05.

Based on our unpublished preliminary study average ONSD results, when
calculated as α error: 0.05, power: 0.80, and effect size 0.40 according to the power
analysis performed with the G * power package program, the sample size was 22 for each
group and 66 in total.

3. Results

The study was completed with 89 patients, 51 female and 38 males. When all
descriptive data are compared, there was no statistically significant differences found
between the groups (p>0.05) (Table 1).

There were no statistically significant differences between the groups in terms of
MAP, HR, P-peak, P-plateau and etCO₂ parameters (p>0.05). However, there were
statistically significant differences between the groups in terms of SpO₂ Saturation
(p=0.022) (Table 2).

There were statistically significant differences observed in variations in right-left
eye ONSD measured before pneumoperitoneum and in the 15th and 30th minutes after
pneumoperitoneum (p<0.05) (Table 3).

In all three groups, there were no statistically significant differences identified for
right and left ONSD values (p>0.05) (Table 4).

4. Discussion

In the current study, we evaluated the effects of different intra-abdominal pressures
during pneumoperitoneum and ONSD measurements. We detected significant increases
in ONSD at the increased abdominal pressures. As the applied pressure value increased, the increase in ONSD values became more pronounced.

Currently laparoscopic interventions have begun to be chosen more often than conventional methods. However, practices like intraabdominal CO₂ insufflation, ensuring imaging success, may involve a range of complications. Intraabdominal pressure increase occurring with CO₂ insufflation increases intrathoracic and ICPs [15].

Studies support that ONSD can be a non-invasive imaging method that can evaluate ICP elevation timely [16-20]. Many studies have confirmed that ONSD changes with the changes in ICP [19-22]. Several studies have addressed specifically how ONSD is affected by acute changes in ICP. Findings showed that the change in ICP was reflected in ONSD measurement rapidly [16,23]. In our study, although there was no change in ONSD measurements measured at the 5th minute after intubation, we observed statistically significant differences between the right-left eye ONSD changes measured at the 15th and 30th minutes after pneumoperitoneum was created. Secondary to this, we thought that the increase in intrabdominal pressure indirectly increased the ICP.

Monitoring of ICP changes is not included among standard monitoring methods for anesthesia. Noninvasive sonographic measurement of ONSD for determination of high ICP has high sensitivity-specificity values and is reported to be an appropriate, accurate and noninvasive screening tool [10,11]. Orbital sonography is completed with a high-frequency linear transducer in B-mode and imaging of the nerve is made perpendicular to the eyeball. Diameter measurement should be performed 3 mm behind the optic disk [24]. It is a technique that is easy to learn and apply, with measurement of 25 patients generally sufficient for experience [25]. Before starting our study, we measured ONSD in 30 patients.
In the references, normal values of ONSD are given as 4mm upper limit for under one year old, 4.5mm for 1-14 years old and 5 mm for older ages [11]. In our study, the mean ONSD value was 4.790±0.347 mm for left eye and 4.796±0.333 mm for the right eye in Group 1; 4.572±0.496 mm for the left eye and 4.606±0.502 mm for the right eye in Group 2; and 4.583±0.494 mm for the left eye and 4.540±0.488 mm for the right eye in Group 3. These values are somewhat below the values in the previous study.

Normally, there is interocular symmetry in both eyes for the ONSD; however, differences in ONSD are reported in situations with unilateral papillary edema or without any cause [26]. As a result, ONSD measurement with USG should be performed in both eyes. Therefore, in our study, we also measured ONSD both eyes in each patient and we did not observe a statistically significant difference between the changes in right and left eye ONSD.

Though Haris et al [27] reported increases in central venous pressure, mean arterial pressure and systemic vascular resistance linked to intraabdominal CO₂ insufflation. In our study there were no statistically significant differences identified between the hemodynamic data in the three groups.

C Robba et al [28] stated in their study that ICP would increase if the pneumoperitoneum and trendelenburg position were applied together. In our study, during pneumoperitoneum with pressures at 10 mmHg, 12 mmHg and 14 mmHg, the ONSD was directly proportional to the increase in abdominal pressure in spite of reverse Trendelenburg position; as a result, it was identified that intracranial blood pressure levels increased.

A study by Sahay et al [29] with 61 patients stated there was an increase in ICP with pneumoperitoneum and Trendelenburg position and that it took at least 5 minutes
for these values to return to basal levels. Similarly, in our study, it was observed that the
increase in ONSD of the patients approached basal values as of the 10th minute after
evacuating the CO₂ from the abdomen.

The results of our study should be considered within some limitations. In the study,
a direct measurement tool could be used in addition to an ICP indirect measurement tool
or orbital sonographic measurement could be supported by the tonometer which is also
an indirect measuring device. A larger sample could be taken into the study. One week
after the surgery is over, another measurement could be taken, so that information about
when ONSD returned to normal could be obtained.

5. Conclusion

In conclusion, a significant increase was observed in ONSD values in direct
proportion to the intrabdominal pressure increase in patients undergoing laparoscopic
cholecystectomy surgery. As the applied pressure value increased, the increase in ONSD
values became more pronounced.

Non-invasive ONSD measurements performed with USG can be a guide in terms
of optimization of intraabdominal pressures, especially in laparoscopic surgeries (patients
with head trauma, CVS, known-unknown intracranial pathology, etc.) where increased
ICP poses a risk. In this way, safer anesthesia can be applied. Additionally, low
pneumoperitoneum pressures should be chosen to preserve ICP in laparoscopic surgeries,
especially in patients with high ICP.

Ethical approval was obtained from the local ethical committee of University of
Health Sciences Okmeydani Training and Research Hospital, Clinical Research Ethics
committee (Ethic Committee: 48670771 – 514.10 document no) and study was completed
at University of Health Sciences Sultan 2. Abdülhamid Han Training And Research Hospital, Department of Anesthesiology.

References


Table 1. Comparison of descriptive data between the study groups

<table>
<thead>
<tr>
<th></th>
<th>Group 1: P= 10 cmH₂O (n=30)</th>
<th>Group 2: P= 12 cmH₂O (n=29)</th>
<th>Group 3: P= 14 cmH₂O (n=30)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female; n (%)</td>
<td>15 (50%)</td>
<td>20 (69%)</td>
<td>16 (53.3%)</td>
<td>0.292a</td>
</tr>
<tr>
<td>ASA-I; n (%)</td>
<td>12 (40%)</td>
<td>12 (41.4%)</td>
<td>14 (46.7%)</td>
<td>0.859a</td>
</tr>
<tr>
<td>Age, years; mean±SD</td>
<td>48.43±13.00</td>
<td>51.27±12.97</td>
<td>47.53±12.61</td>
<td>0.511b</td>
</tr>
<tr>
<td>Height, cm; mean±SD</td>
<td>169.10±7.97</td>
<td>166.13±8.19</td>
<td>168.56±8.12</td>
<td>0.332b</td>
</tr>
<tr>
<td>Weight, kg; mean±SD</td>
<td>75.40±8.82</td>
<td>72.96±11.62</td>
<td>77.26±11.61</td>
<td>0.311b</td>
</tr>
<tr>
<td>BMI, kg/m²; mean±SD</td>
<td>26.40±3.04</td>
<td>26.42±3.73</td>
<td>27.12±3.20</td>
<td>0.640b</td>
</tr>
</tbody>
</table>

ASA-I: American Society of Anesthesiologists physical status classification-I, BMI: Body Mass Index, a: Chi-square test, b: One-way ANOVA test.

Table 2. Comparison of hemodynamic data between the study groups before pneumoperitoneum

<table>
<thead>
<tr>
<th></th>
<th>Group 1: P=10 cmH₂O</th>
<th>Group 2: P=12 cmH₂O</th>
<th>Group 3: P=14 cmH₂O</th>
<th>p value</th>
</tr>
</thead>
</table>


<table>
<thead>
<tr>
<th></th>
<th>Group 1: P=10 cmH2O</th>
<th>Group 2: P=12 cmH2O</th>
<th>Group 3: P=14 cmH2O</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean Arterial Pressure, mmHg; mean±SD</strong></td>
<td>82.93±10.86</td>
<td>82.24±10.75</td>
<td>86.46±9.32</td>
<td>0.347a</td>
</tr>
<tr>
<td><strong>Heart Rate, beats/min; mean±SD</strong></td>
<td>71.43±11.11</td>
<td>67.34±12.04</td>
<td>69.76±11.06</td>
<td>0.389a</td>
</tr>
<tr>
<td><strong>Pressure-peak, cmH2O; mean±SD</strong></td>
<td>20.70±1.62</td>
<td>21.41±2.79</td>
<td>21.10±2.39</td>
<td>0.498a</td>
</tr>
<tr>
<td><strong>Pressure-plateau, cmH2O; mean±SD</strong></td>
<td>9.66±0.71</td>
<td>10.10±1.04</td>
<td>9.90±0.99</td>
<td>0.200a</td>
</tr>
<tr>
<td><strong>SpO2 Saturation, %; mean±SD</strong></td>
<td>97.56±1.19</td>
<td>97.13±1.90</td>
<td>98.20±1.15</td>
<td>0.022*,a,*,c</td>
</tr>
<tr>
<td><strong>End-tidal CO2, %; mean±SD</strong></td>
<td>33.30±1.82</td>
<td>32.51±2.92</td>
<td>33.36±2.18</td>
<td>0.310a</td>
</tr>
</tbody>
</table>

*: One-way ANOVA test, *:p<0.05, €: Group II & Group III= p<0.05.

**Table 3.** Comparison of ONSD Variation caused by pneumoperitoneum between the study groups

- **Difference between ONSD measurement before pneumoperitoneum and in 15th minute of pneumoperitoneum**
  - **Left eye, mm; mean±SEM**
    - Group 1: 0.050±0.082
    - Group 2: 0.196±0.018
    - Group 3: 0.376±0.218
    - p: 0.001*,a,*,b,*,c
  - **Right eye, mm; mean±SEM**
    - Group 1: 0.050±0.177
    - Group 2: 0.134±0.234
    - Group 3: 0.456±0.274
    - p: 0.001*,a,*,b,*,c

- **Difference between ONSD measurement before pneumoperitoneum and in 30th minute of pneumoperitoneum**
  - **Left eye, mm; mean±SEM**
    - Group 1: 0.053±0.190
    - Group 2: 0.206±0.237
    - Group 3: 0.463±0.363
    - p: 0.001*,a,*,b,*,c
  - **Right eye, mm; mean±SEM**
    - Group 1: 0.060±0.282
    - Group 2: 0.165±0.239
    - Group 3: 0.480±0.304
    - p: 0.001*,a,*,b,*,c

- **Difference between ONSD measurement before pneumoperitoneum and after pneumoperitoneum**
  - **Left eye, mm; mean±SEM**
    - Group 1: 0.003±0.182
    - Group 2: 0.048±0.241
    - Group 3: 0.010±0.322
    - p: 0.342a
  - **Right eye, mm; mean±SEM**
    - Group 1: 0.010±0.193
    - Group 2: 0.020±0.250
    - Group 3: 0.040±0.347
    - p: 0.423a

ONSD: optic nerve sheath diameter, *: One-way ANOVA test, *:p<0.05, €: Group I & Group II= p<0.05, β: Group I & Group III= p<0.05, €: Group II & Group III= p<0.05.
**Table 4.** Comparison of right and left eye optic nerve sheath diameters of study groups before pneumoperitoneum

<table>
<thead>
<tr>
<th></th>
<th>Group 1: P= 10 cmH$_2$O</th>
<th>Group 2: P= 12 cmH$_2$O</th>
<th>Group 3: P= 14 cmH$_2$O</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left eye ONSD, mm; mean±SD</strong></td>
<td>4.790±0.347</td>
<td>4.572±0.496</td>
<td>4.583±0.494</td>
<td>0.117$^a$</td>
</tr>
<tr>
<td><strong>Right eye ONSD, mm; mean±SD</strong></td>
<td>4.796±0.333</td>
<td>4.606±0.502</td>
<td>4.540±0.488</td>
<td>0.076$^a$</td>
</tr>
</tbody>
</table>

ONSD: optic nerve sheath diameter, $^a$: One-way ANOVA test