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Research article

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Effects of pneumoperitoneum and patient position on intracranial pressure in obese patients undergoing laparoscopic cholecystectomy

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Ethics Committee Approval
The approval was taken from the Necmettin Erbakan University Ethics Committee of Non-Pharmaceutical and Non-Medical Device Researches (Decision No: 2018/1494).
All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

Conflict of Interest
No conflict of interest was declared by the authors.

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Abstract

Background/Aim: Optic nerve sheath diameter (ONSD) measurement is one of the non-invasive techniques used for intracranial pressure (ICP) measurement. ICP changes have been evaluated based on ONSD measurements during many laparoscopic surgeries. However, such analyses in the obese patient populations are limited. This study aimed at investigating the effects of pneumoperitoneum and reverse Trendelenburg and head-up position on ICP based on ONSD measurements in obese patients undergoing laparoscopic cholecystectomy.
Methods: This observational study included 60 female patients who were scheduled for laparoscopic cholecystectomy. Obese patients with a body mass index (BMI) of 30 and above were assigned to Group 1, while BMI < 30 patients were assigned to Group 2. The first ONSD measurement was performed just before insufflation (T1). The second measurement was taken 5 min after insufflation (T2), the third measurement 5 min after placing patients in the reverse Trendelenburg and head-up position (T3), and the last measurement 5 min after the deflation while the reverse Trendelenburg and head-up position was maintained (T4).
Results: ONSD measurements at the T2 and T3 time points in Group 1 patients were higher than in Group 2 patients ($P = 0.012$ versus $P = 0.020$). Both measurement values were higher in obese patients. In Group 1 patients, T2 and T3 measurements were significantly higher than T1 and T4 measurements (T2 > T1; $P < 0.001$, T2 > T4; $P < 0.001$, T3 > T1; $P < 0.001$, and T3 > T4; $P < 0.001$). No significant difference between T2 and T3 and between T1 and T4 measurements were found. In Group 2 patients, T2 measurements were significantly higher than the T1, T3, and T4 measurements, while T3 measurements were significantly higher than T1 and T4 measurements (T2 > T1; $P < 0.001$, T2 > T3; $P = 0.022$, T2 > T4; $P < 0.001$, T3 > T1; $P < 0.001$, and T3 > T4; $P = 0.048$). No significant difference between T1 and T4 measurements was noted.
Conclusion: Laparoscopic cholecystectomy does not cause an increase in ICP of obese patients with limited pneumoperitoneum pressure, reverse Trendelenburg and head-up position, and controlled anesthesia.

Keywords: Optic nerve, Obesity, Laparoscopy, Cholecystectomy

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Introduction

Cholelithiasis is one of the most prevalent gastrointestinal diseases in adults, and obesity is one of the important risk factors associated with an increase in the risk of developing cholelithiasis [1]. Obesity is defined as a body mass index (BMI) greater than 30 kg/m^2 with an increasing prevalence among all racial groups, genders, and people of different educational levels [2]. Laparoscopic cholecystectomy is a surgical technique frequently used for cholelithiasis treatment. For performing this surgery, pneumoperitoneum is created by the insufflation of CO_2. While obesity was formerly considered a contraindication for laparoscopic surgery, nowadays, laparoscopy is considered to be a safe, effective, and the procedure of choice for obese patients when it is performed by experienced surgeons [3].

Pneumoperitoneum and the resulting increase in intra-abdominal pressure cause decreased venous return, and CO_2 absorption from the peritoneal surface leads to hypercapnia and respiratory acidosis. Hemodynamic and respiratory side effects are moderate and often well-tolerated. While the results concerning the effects of pneumoperitoneum on intracranial pressure (ICP) are limited, a positive correlation has been shown between intra-abdominal pressure and ICP [4]. Intra-peritoneal pressure causes an increase in intra-thoracic pressure by causing an elevation of the diaphragm and an increase in central venous pressure with compression of the inferior vena cava. Elevated central venous pressure results in an increase in cerebrospinal fluid pressure, thereby leading to an increase in ICP [5]. Another reason for an increase in ICP is arterial vasodilation caused by a CO_2 increase [6].

Although invasive techniques have been indicated to be the gold standard for intracranial pressure measurements, the literature data also show the feasibility of non-invasive techniques. Ultrasonographic measurement of optic nerve sheath diameter (ONSD) is one such technique [7]. Changes in ICP have been analyzed using ONSD measurements during many laparoscopic surgeries and in different patient positions [8,9]. However, analyses in the obese patient populations are limited, and as far as we know, no study in the literature that analyzes the effect of pneumoperitoneum on ICP in the reverse Trendelenburg and head-up position has been published. Obesity is associated with an increase in intra-abdominal pressure, which can become chronic without noticeable clinical signs and result in intracranial hypertension [5]. Patients undergoing laparoscopic surgery are at risk of an increase in ICP, and ICP monitoring is important for critically ill patients.

This study aimed to investigate the effects of pneumoperitoneum and reverse Trendelenburg and head-up position in laparoscopic cholecystectomy surgery based on non-invasive ONSD measurements on ICP in obese patients.

Materials and methods

This prospective observational study was conducted in an academic university hospital between September 2019 and October 2020 in accordance with the principles of the Declaration of Helsinki after obtaining approval from the University Ethics Committee (Decision Number: 2018/1494, Approval Date: 14/09/2018). A written informed consent form was obtained from all patients who agreed to participate in the study. The study included female patients aged 18–65 years with an American Society of Anesthesiologists (ASA) score of I/II who were scheduled for elective laparoscopic cholecystectomy surgery. Patients with ASA III/IV class, intracranial pathology, a history of cerebrovascular disease, a history of ocular pathology or disease, and pregnant patients were excluded from the study. Patients were monitored using an electrocardiogram (ECG), pulse oximeter, and noninvasive arterial pressure measurement. Muscle relaxation of patients was monitored with a neuromusculer transducer (NMT; SJC17200038HA, GE Healthcare, Helsinki, Finland). Anesthesia was induced with 1 mcg/kg remifentanil (Rentanil, VEM, Tekirdağ, Turkey), 2 mg/kg propofol (Propofol %1 Fresenius, Fresenius Kabi AB, Uppsala, Sweden) and 0.6 mg/kg rocuronium (Myocron, VEM, Tekirdağ, Turkey). When the train of four (TOF) count was 0, patients were intubated and anesthesia was maintained with desflurane (Suprane, Baxter Healthcare, Puerto Rico, USA) inhalation in 50% oxygen–air mixture and intravenous (iv) remifentanil infusion. Desflurane and remifentanil were titrated to maintain vital values within a range of 20% of the baseline values. Tidal volume and respiratory rates were adjusted to maintain end-tidal CO_2 levels between 35 and 40 mmHg. Patients were given iv 2 mg/kg tramadol (Tradolex, Mefar, İstanbul, Turkey) for post-operative analgesia and iv 4 mg ondansetron (Zofran, GlaxoSmithKline, Research Triangle Park, England) for nausea and vomiting. In the pneumoperitoneum procedure, the pressure was limited to 12 mmHg. Age, ASA score, BMI, pneumoperitoneum time, and post-operative nausea and vomiting were recorded for all patients.

Ultrasonographic measurement of optic nerve sheath diameter

The ONSD values of patients were measured by ultrasonography (USG) at four different time points. Measurements were taken by a trained anesthesiologist who was not involved in the study. A 12.0 MgH linear USG probe (Esaote MyLab Six CrystaLine, Genova, Italy) with a thin layer of gel was carefully placed on the closed upper eyelid. Avoiding excessive pressure, the probe was adjusted to display the optic nerve insertion into the eyeball in two-dimensional (2D) mode. After providing optimal contrast enhancement between the hypoechoic image of the optic nerve and the echogenicity of the retrobulbar adipose tissue, the image was frozen. ONSD was measured at 3 mm behind the optic disc using the electronic caliper of the USG (Figure 1).

Figure 1: Ultrasonographic image of optic nerve sheath diameter (ONSD) measurement

The measurement was repeated four times for a single eye, two times horizontally and two times vertically, and the average of these four measurements was considered the ONSD. Measurements were obtained at four different time points from the same eye. The measurement time points were defined as T1 (before pneumoperitoneum when the patient was in the supine position), T2 (5 min after pneumoperitoneum when the patient was in the supine position), T3 (pneumoperitoneum and after the patient was placed in the reverse Trendelenburg and head-up position), and T4 (5 min after pneumoperitoneum termination when the patient was in the reverse Trendelenburg and head-up position). At these four time points, the heart rates, noninvasive mean arterial pressures, and end-tidal CO_2 values of patients were also recorded in addition to the ONSD measurements. Moreover, heart rates and noninvasive mean arterial pressures were recorded when patients were first monitored, after induction of anesthesia, and after intubation. Patients were placed in the reverse Trendelenburg and head-up position by the anesthesiologist, who would measure the ONSD under the guidance of the surgeon.

Statistical analysis

The data obtained in the study were analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 23.0 (IBM SPSS 23.0 for Windows, Armonk, New York, United States). Frequencies of general demographic characteristics and descriptive statistical values of all time-dependent measurements were indicated. When examining the normality of values between the groups, the Shapiro–Wilk test was applied if n was < 30, and the Kolmogorov–Smirnov test was applied if n was > 30. The values were considered to be non-normally distributed between the groups if P was < 0.05 and normally distributed between the groups if P > 0.05. As a result of the normality test, the Mann–Whitney U test was used for non-normally distributed variables, while the independent samples t-test was used for normally distributed variables to examine intergroup differences. A chi-squared test was used when examining intergroup dependency in categorical data. When examining the intergroup difference and dependency, the level of statistical significance was set at 0.05, and a P < 0.05 was considered to indicate a significant difference between the groups, while a P > 0.05 was considered to indicate none. The Wilcoxon signed-rank test was used to examine the differences between the intra-group time-dependent measurement values. P < 0.05 was considered to indicate a change in measurement values over time, while a P > 0.05 was considered to indicate no change over time.

Sample size

The sample size of the study was calculated using the G*Power software for Windows, version 3.1.9.4 (Universität Düsseldorf, Düsseldorf, Germany) based on the data set consisting of 10 patients (obese: 5, non-obese: 5). The results of the pilot study showed that the ONSD measured 5 min after pneumoperitoneum while the patient was in the supine position was 4 (0.3) (mean [standard deviation {SD}]) in the obese group, while it was 3.8 (0.3) in the non-obese group. The sample size required to detect a 30% difference was determined as 30 patients for each group, 60 patients in total with 80% power and 0.05 margin of error. Obese patients were classified as Group 1, while non-obese patients were classified as Group 2.

Results

The study included 60 female patients. No patient was excluded from the study, and data from a total of 60 patients were analyzed (Figure 2). Considering the distribution of demographic data among the groups, the mean weight and BMI values of the patients in Group 1 were higher than the patients in Group 2 (P < 0.001 versus P < 0.001). In addition, while all of the patients in Group 1 were ASA 2, only 20 of the patients in Group 2 were ASA 2 patients (P = 0.001). The distribution of demographic data between the two groups is given in Table 1.

Figure 2: Flowchart of the study

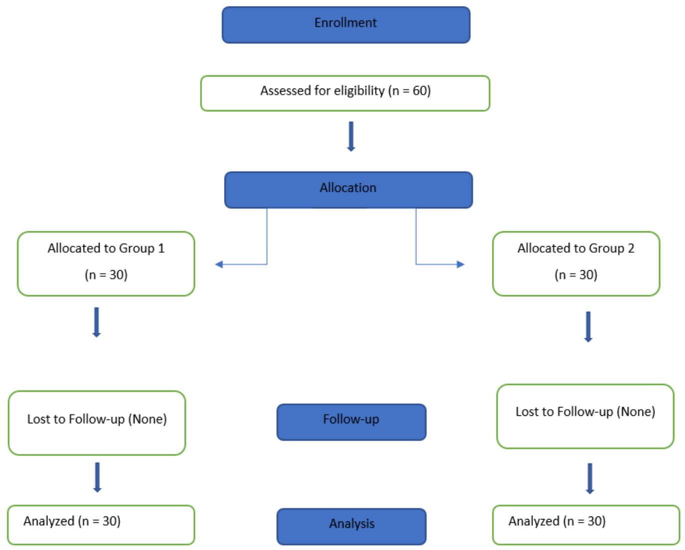


Table 1: Distribution of demographic data (mean [SD])

	Group 1 (n = 30)	Group 2 (n = 30)	*P*-value
Age (year)	48.77 (10.37)	42.97 (14.11)	0.075
Weight (kg)	91.37 (10.07)	68.33 (8.49)	< 0.001
Height (cm)	161.17 (5.87)	164.27 (7.84)	0.122
BMI (kg/m^2)	35.19 (3.28)	25.28 (2.19)	< 0.001
ASA (I/II)	0 / 30	10 / 20	0.001

SD: standard deviation, BMI: Body mass index, ASA: American Society of Anesthesiologists

The pneumoperitoneum time was 40.2 (9.0) min in Group 1 and 40.6 (7.9) min in Group 2. No statistically significant difference between the groups in terms of pneumoperitoneum time (P = 0.855) was found. Considering the presence of post-operative nausea/vomiting, 20 (66.7%) patients in Group 1 and 27 (90%) patients in Group 2 had nausea/vomiting; however, the difference was not statistically significant (P = 0.060).

ONSD measurements at the T2 and T3 time points in Group 1 patients were higher than Group 2 patients (P = 0.012 versus P = 0.020). Both measurement results were higher in obese patients than in non-obese patients (Table 2).

Table 2: Differences in ONSD measurements between the groups (mean [SD])

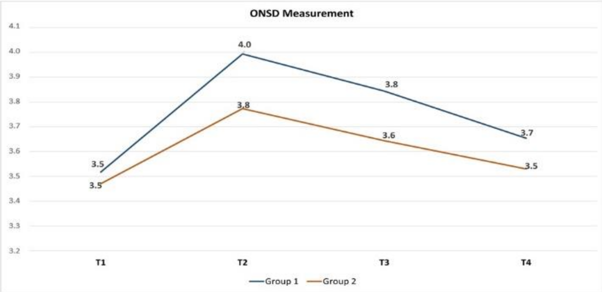
	Group 1 (n = 30)	Group 2 (n = 30)	*P*-value
ONSD T1 (mm)	3.5 (0.31)	3.5 (0.30)	0.556
ONSD T2 (mm)	4.0 (0.30)	3.8 (0.29)	0.012
ONSD T3 (mm)	3.8 (0.32)	3.6 (0.28)	0.020
ONSD T4 (mm)	3.7 (0.32)	3.5 (0.26)	0.260

SD: standard deviation, ONSD: Optic Nerve Sheath Diameter

The analysis of the changes in ONSD measurements of Group 1 revealed significantly higher T2 and T3 measurements than T1 and T4 measurements (T2 > T1; P < 0.001, T2 > T4; P < 0.001, T3 > T1; P < 0.001, and T3 > T4; P = 0.001), but no significant differences between T2 and T3 measurements and between T1 and T4 measurements were found. In Group 2 patients, T2 measurements were significantly higher than T1, T3, and T4 measurements, while T3 measurements were significantly higher than T1 and T4 measurements (T2 > T1; P < 0.001, T2 >

T3; $P = 0.022$, T2 > T4; $P < 0.001$, T3 >T1; $P < 0.001$, and T3 > T4; $P = 0.048$). No significant difference between T1 and T4 measurements was noted (Figure 3).

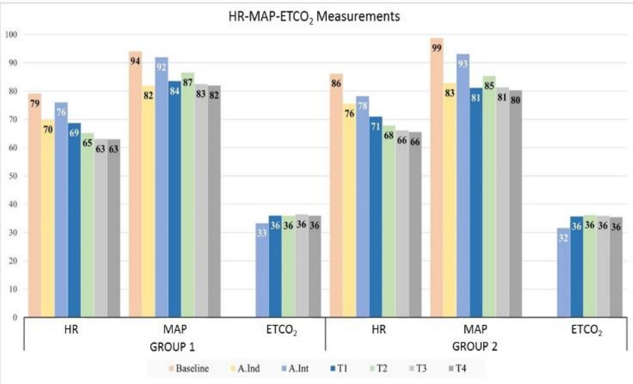
Figure 3: Changes in ONSD measurements by time (mm)



ONSD: Optic Nerve Sheath Diameter

No statistically significant difference between the groups in terms of changes in heart rate, mean arterial pressure, and end-tidal CO_2 values over time were found ($P > 0.05$) as shown in Figure 4.

Figure 4: Changes in HR, MAP, and $ETCO_2$ values by time



HR: Heart rate, MAP: Mean arterial pressure, $ETCO_2$: End-tidal CO_2, A.Ind: After Induction, A.Int: After Intubation

Discussion

This study investigated the effects of pneumoperitoneum and reverse Trendelenburg and head-up position on ICP in obese patients undergoing laparoscopic cholecystectomy. The results of the study demonstrated that ONSD was increased by pneumoperitoneum in both obese and non-obese patients, while this increase was more significant in obese patients. The reverse Trendelenburg and head-up position after pneumoperitoneum caused a significant decrease in ONSD values of non-obese patients. The reverse Trendelenburg and head-up position maintained after the termination of pneumoperitoneum caused ONSD measurements to approach baseline values in both obese and non-obese patients. The measurements showed no ONSD value suggestive of an increased ICP in any patient.

Laparoscopic cholecystectomy is the gold standard treatment for benign gallstone disease [10]. The requirement for creating pneumoperitoneum may cause various intra- and post-operative hemodynamic and metabolic complications in these patients. A definite positive correlation between increased ICP and high intra-abdominal pressure has been reported in the literature [11]. Obesity is associated with an increase in intra-abdominal pressure and ICP, and this relationship may lead to an increase in the side effects caused by pneumoperitoneum [5]. The gold standard for ICP measurement is invasive measurement techniques. However, these techniques may cause serious complications, such as bleeding and infection, and their use is difficult in routine practice for short-term surgical procedures [12]. It has been shown that ONSD is affected by ICP changes and can be used as a non-invasive measurement technique [13]. The optic nerve is part of the central nervous system and is surrounded by the dural sheath. In cases of increased ICP, the sheath expands, and changes in the diameter of the nerve sheath can be visualized by transocular USG [14].

In the literature, no consensus on the threshold for ONSD measurement value for increased ICP can be found. Shirodkar et al. [15] found high sensitivity and specificity for cut-off values of 4.6 mm in women and 4.8 mm in men. Amini et al. [16] found that values greater than 5.5 mm showed an increase in ICP with 100% sensitivity and specificity. Another study suggested that values greater than 5 mm indicated an elevation in ICP values that may require intervention [17]. Therefore, a broad variation in the optimal cut-off values of ONSD compared to invasive ICP monitoring exists [18]. Because of ethnicity and gender differences, ONSD measurement values and cut-off values for ICP increase may be different. The study by Goeres et al. [19] with a healthy cohort determined a mean basal value of 3.78 mm for men and 3.60 mm for women. The same study found a cut-off value of 4.11 mm for an increase in the ICP increase with a 95% confidence interval in women, arguing that it might have more clinical benefits than the generally accepted level of 5 mm. This value is also the lowest cut-off value we have found in the literature. Most of the ONSD studies on laparoscopic surgery have baseline values of 4.00 mm and above. For our country's population, no study to determine the mean ONSD and cut-off value for ICP in healthy individuals is available. In our study, the mean baseline ONSD was found to be 3.5 mm in both groups. Since the initial measurements were performed after the induction of anesthesia, these values could be attributed to the presence of deep anesthesia. The highest mean value was found to be 4.0 (0.3) in obese patients and 3.8 (0.29) in non-obese patients. Therefore, these results show that 12 mmHg pneumoperitoneum and laparoscopic cholecystectomy performed in the reverse Trendelenburg and head-up position do not lead to an increase in ICP in either obese or non-obese patients even if the lowest cut-off value reported in the literature is used. Considering the fact that all patients included in the study were female, the reason for the absence of significant increases in ONSD measurements, including obese patients, may be due to the effect of previous pregnancies and the presence of higher abdominal wall compliance with the effect of increased volume in obese patients. A need for further studies to clarify the physiopathology of these results exists.

Obese patients tolerate laparoscopic procedures very well. The normal intra-abdominal pressure of non-obese individuals is 5 mm Hg or lower [20]. In contrast, morbidly obese patients have chronically high intra-abdominal pressures of 9 to 10 mmHg [21]. In general, CO_2 absorption and excretion in morbidly obese people are similar to non-obese people. Changes in the cardiac index have also been found to be similar [22]. In our study, no statistically significant differences between the groups in terms of changes in heart rate, mean arterial pressure, and end-tidal CO_2 values over time were found. Similar results in terms of hemodynamic parameters with non-obese patients and even in morbidly obese patients are in line with our results, and it is not surprising to find no differences in hemodynamic parameters of obese patients. Considering the relationship of high intra-abdominal pressure with high ICP, we anticipated encountering higher ONSD measurements in obese patients. The study of Dip et al. [5] comparing ONSD in obese and non-obese patients found a significant difference 30 min after pneumoperitoneum. In laparoscopic procedures, a minimum of 10 to15 min is required for an increase in partial pressure of carbon dioxide ($PaCO_2$) after pneumoperitoneum, and the increase in ICP by small volume increments with involved homeostatic mechanisms is kept within a narrow range [23]. When this compensatory effect is exhausted, substantial increases are observed in ICP in direct proportion to the increase in volume [24]. The measurements at the T2 and T3 time points in the study were obtained in the presence of pneumoperitoneum and during the first 10 min. If measurements were performed after longer periods, perhaps higher values would have been found. Moreover, the Dip study was conducted on both male and female patients who underwent different surgical procedures under 14 mmHg pressure, and ONSD measurements were found that suggested high ICP of 86%. The authors stated that the incidence of ICP increase was significant in obese and non-obese patients who underwent laparoscopic procedures. No such result was found in our study. We believe that the reason for this different result is due to the fact that the pneumoperitoneum pressure, which was 14 mmHg in the Dip study, was 12 mmHg in our study. Furthermore, the study by Dip also included morbidly obese and super-obese patients. Our study, on the other hand, included only obese patients. Another reason for the different results may be the existing increased chronic intracranial pressure in morbidly obese and super-obese individuals.

In laparoscopic cholecystectomy, appropriate surgical conditions are provided by pneumoperitoneum and reverse Trendelenburg and head-up position. One of the most studied parameters associated with ICP in laparoscopic surgeries is patient position. Numerous studies showing that the Trendelenburg position causes an increase in ONSD have been published [7, 25]. A study on anesthetized neurosurgery patients revealed that the head-down position and head rotation can lead to significant increases in ICP [22]. An animal study by Halverson et al. [26] revealed that increased ICP resulting from CO_2 insufflation was aggravated in the Trendelenburg position and not relieved when the reverse Trendelenburg position was used. However, the animal study of Rosenthal [27] reported that the highest and lowest ICP values during CO_2 pneumoperitoneum were observed in the Trendelenburg and reverse Trendelenburg positions, respectively. Our study results are consistent with the study results of Rosenthal as the reverse Trendelenburg and head-up position led to a reduction in ONSD in the presence of pneumoperitoneum in non-obese patients and after deflation in both groups. The study of Sahay et al. [8], which investigated the effects of the Trendelenburg and reverse Trendelenburg positions in non-obese female patients found that pneumoperitoneumn in addition to both positions led to an increase in ONSD measurements with the increase being more pronounced in the Trendelenburg position. The measurements did not approach baseline values even at 5 min after deflation. The pneumoperitoneum pressure in the study was the same as in our study, and a 20° reverse Trendelenburg position was used. In our study, we attempted to provide a 30° reverse Trendelenburg position. For this reason, the effects of the reverse Trendelenburg position may have been found to be different. In our last measurement study, the reverse Trendelenburg and head-up position was used after deflation. In the study of Sahay, on the other hand, the last measurement was performed in the supine position after deflation. We believe that the reverse Trendelenburg and head-up position we maintained after deflation has an effect on reaching the baseline values in as short a time as 5 min.

Studies investigating the effect of the 10° reverse Trendelenburg position in craniotomy surgery have found a decrease in ICP without deterioration of cerebral perfusion pressure [28–30]. It has been found that the 30° reverse Trendelenburg position provides a reduction in ICP of approximately 1 mmHg [31]. The 30° head-up position has been shown to cause a significant reduction in cerebral blood volume in healthy surgical patients based on a near-infrared spectroscopy reading [32]. The study of Demirgan et al. [33] found that placing the patient in the reverse Trendelenburg position before establishing pneumoperitoneum at a pressure of 15 mmHg in patients undergoing laparoscopic cholecystectomy prevented the increase in ONSD. The Trendelenburg position causes an increase in preload due to an increase in venous return from the lower limbs. This position causes a cephalic shift of the internal organs, which leads to an increase in the pressure on the diaphragm. In the reverse Trendelenburg position, the internal organs shift caudally, causing a reduction in the pressure on the diaphragm and improvement in respiratory function. Therefore, we expect the side effects of increased intra-thoracic pressure, one of which is increased ICP, to be reversed. From this point of view, we anticipated that the reverse Trendelenburg and head-up position used in cholecystectomy surgery would lead to a reduction in ONSD measurements with the opposite effect. As we predicted, in both obese and non-obese patients, the position produced a decrease in ONSD measurements compared to measurements taken after pneumoperitoneum. However, this decrease was statistically significant in non-obese patients. In both groups, the position did not cause a return to the baseline measurement values after anesthesia induction. This return to baseline was achieved when the position was maintained after the termination of pneumoperitoneum in both groups. Therefore, we believe that the reverse Trendelenburg and head-up position should be maintained in obese and non-obese patient groups undergoing laparoscopic surgery until the recovery process is completed unless a surgical contraindication exists. However, more studies are needed to explain the background of the fact that the effect of position in the presence of pneumoperitoneum in obese patients is not as pronounced as in non-obese patients.

Another well-studied parameter associated with ICP in laparoscopic surgeries is pneumoperitoneum pressure. A study investigating the effects of pneumoperitoneum created with 8 and 14 mmHg pressure emphasized the significance of low pressure to reduce changes in ICP [34]. The study was performed on patients undergoing laparoscopic cholecystectomy under propofol anesthesia in a 30° reverse Trendelenburg position, and ONSD measurements above 5.2 were considered a significant change, while ONSD measurements above 5.7 were considered the threshold value to terminate pneumoperitoneum. In the study with a mean pneumoperitoneum time of 78 min, a value above 5.2 was mostly determined in the high-pressure group. Another study investigating the effect of pneumoperitoneum pressure in laparoscopic cholecystectomy compared the effects of 10, 12, and 14 mmHg pressure [35]. The study was performed under sevoflurane anesthesia and found that ONSD measurements increased as the applied pressure increased. Both studies were performed with non-obese patients. In our study, we used a pressure of 12 mmHg and our mean pneumoperitoneum time was 40 min. We did not find any measurement values suggestive of increased ICP values in either the obese or non-obese groups. We think that in addition to the reverse Trendelenburg and head-up position, the use of 12 mmHg pressure and the duration of pneumoperitoneum significantly contributed to this result. We are of the opinion that a pneumoperitoneum pressure of 12 mmHg should be preferred to higher values during short-term laparoscopic surgeries of obese patients. However, a need for studies comparing ONSD measurements in laparoscopic surgeries performed at different times and under different pressure values to determine the safe pressure value in obese patients is present.

Volatile anesthetics have vasodilatory activity on vascular smooth muscle. This vasodilatory activity is evident above 1.0 MAC and can cause a significant increase in cerebral blood flow, resulting in an increase in ICP. In a pig model, this increase was shown to be higher in desflurane compared to sevoflurane and isoflurane [36]. Verdonck et al. [37] reported that ONSD remained stable during robot-assisted laparoscopic radical prostatectomy and ONSD measured 10 min after pneumoperitoneum combined with the Trendelenburg position did not increase under general anesthesia maintained with sevoflurane. The study of Kim et al. [9] using desflurane showed a slight but controllable increase in ONSD measured after induction of anesthesia and Trendelenburg position without pneumoperitoneum. The reason for this result was explained by the authors as the maintenance of anesthesia with desflurane at 1 to 1.5 MAC in all registered patients. Desflurane at more than 1 MAC was not used in any patient in the study. It would not be correct to speculate on the clear effect of desflurane anesthesia since no measurement was taken before anesthesia induction. However, we believe that the use of desflurane at 1 MAC or below does not cause a significant increase in ICP in obese and non-obese patients based on measurements made at other time points.

Carbon dioxide (CO_2), a potent cerebral vasodilator, is associated with an increase in ICP [6]. Therefore, strict control of $PaCO_2$ will prevent an increase in ICP. End-tidal CO_2 concentration is a non-invasive parameter used as an indirect indicator of $PaCO_2$. $PaCO_2$ increases due to the diffusion of CO_2 from the peritoneum during pneumoperitoneum thus leading to an increase in ICP [27]. However, the dynamic response of ONSD associated with acute $PaCO_2$ change, which may affect ICP, is unclear. The study of Kim et al. [38] in which the effects of short-term hyperventilation on ONSD in patients under general anesthesia were. investigated found that ONSD diameters, which were measured as 0.5 mm with 40 mmHg, decreased to 4.0 mm at 30 mmHg. End-tidal CO_2, which was measured at different time points in the study, was maintained in the 36 mmHg range in both groups and never exceeded 40 mmHg at any time interval. We believe that continuous monitoring of end-tidal CO_2 concentration and maintaining this value within certain limits have an effect on the absence of an increase in ICP in both groups and the ONSD approach to baseline values after deflation.

Limitations

The present study has some limitations. The preferred position of surgeons for laparoscopic cholecystectomy in our institution is the 30° reverse Trendelenburg position. No electronic inclinometer was used while positioning. The position was given by the anesthesiologist, who would measure ONSD under the guidance of the surgeon. Although the anesthesiologist was the same, different surgical teams performed surgeries in the study. This may have prevented the complete standardization of the given position and our ability to achieve objective results. If we had monitored the depth of anesthesia using bispectral index and entropy and had seen the $PaCO_2$ values concurrently with the end-tidal CO_2, we could have interpreted the effects of the anesthesia parameters that we used on the measurement results more objectively. The lack of concurrent invasive measurement with the transocular USG may have caused us to fail to exclude an increase in ICP. No threshold value was defined for ONSD when detecting an increase in ICP. This lack of definition prevented us from achieving a clear result regarding an increase in ICP. ONSD ultrasound is operator-dependent and therefore subject to variability [39]. Measurements were performed by one person to minimize variability. Due to the single-observer strategy, we could not examine the inter-observer variability described and suggested by Dubourg et al. [40]. Another limitation of this study is the lack of capability to compare ONSD measurements with a standard imaging modality, such as computed tomography or magnetic resonance imaging. Not measuring ONSD before induction of anesthesia when the patients were awake, after intubation, and after extubation in the recovery room may have prevented us from detecting possible intubation- and extubation-related effects, both of which may cause a change in ICP. Moreover, if the measurements were taken in the supine position after deflation, the effect of the reverse Trendelenburg position on the restoration of ONSD measurements could be shown more clearly. The sample size and 80% power of the study can be indicated as another limitation.

Conclusion

Laparoscopic cholecystectomy does not cause an increase in ICP of obese patients with a limited pneumoperitoneum pressure, reverse Trendelenburg and head-up position, and controlled anesthesia. It would be beneficial to maintain the reverse Trendelenburg and head-up position after deflation, especially in patients in whom increased ICP would pose a risk.

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