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Comparison of extraperitoneal and intraperitoneal laparoscopic procedures for intracranial pressure increase: a prospective clinical study

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Abstract. – OBJECTIVE: According to the literature, higher levels of both intracranial pressure (ICP) and intraabdominal pressure (IAP) are related in a way that suggests a causal relationship. An increase in ICP can cause major neurological problems both during and after laparoscopic surgery. In this study, we aimed to examine the increase in ICP between totally extraperitoneal (TEP) inguinal hernia repair and laparoscopic cholecystectomy.

PATIENTS AND METHODS: We investigated 52 individuals who underwent laparoscopic surgery for the treatment of inguinal hernia (n = 26) or had a laparoscopic cholecystectomy (n = 26). The optic nerve sheath diameter (ONSD) was assessed before the procedure (T0), 10 minutes after carbon dioxide insufflation (T1), and immediately before extubation (T2).

RESULTS: There were significant differences in the ONSD values between the two groups as a function of time (p = 0.001). In terms of ONSD, the laparoscopic cholecystectomy value (LV) group showed a greater shift from T0 to T1 and T2 than the inguinal hernia value (HV) group. At T1, the ONSD values of both groups were considerably higher than those of T0 and T2. The impact of the extraperitoneal and transperitoneal laparoscopic methods on ICP was investigated. The ONSD value reached its maximum at T1 in both groups. At all measurement periods, the ONSD values of the LV group were noticeably higher than those of the HV group.

CONCLUSIONS: The diagnostic accuracy of ONSD ultrasonography is an important approach for determining the ICP level. During the decision-making process of TEP inguinal hernia repair, this study can guide medical professionals in the evaluation of elevated ICP.

Key Words:
Monitoring intracranial pressure, Laparoscopic Surgery, Optic nerve sheath diameter.

Introduction

Laparoscopic procedures are becoming highly common in general surgery. Laparoscopic cholecystectomy, for instance, is one of the most common procedures in the United States, with 1 million cases annually[1]. Laparoscopy offers numerous advantages for both the patient and the surgeon, including early discharge, quick recovery, and early return to daily life. However, although laparoscopic procedures have benefits, they might cause difficulties in the cardiovascular, neurological, and respiratory systems, as well as an increase in intraabdominal pressure (IAP) due to pneumoperitoneum. Longer laparoscopic procedures increase the likelihood of neurological problems.

Elevated intracranial pressure (ICP) is one of these neurological consequences. It was shown that there is a significant correlation between increased ICP and increased IAP[2]. Acutely elevated IAP increases the diaphragm, constricts the inferior vena cava, and elevates intrathoracic pressure. This increases the central vein pressure. Venous stasis and increased pressure in the sagittal sinus cause diminished cerebrospinal fluid reabsorption and increased ICP[3]. During laparoscopic procedures, an elevated ICP might cause severe neurological consequences[4-8].

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To prevent these problems, ICP should be regularly monitored. Intraventricular and intraparenchymal catheterization is the standard for measuring and monitoring ICP[9,10]. However, this technique is impractical due to the potential for severe consequences such as hemorrhaging and infection[11]. Recent studies[9,12] indicate that ultrasonic assessment of optic nerve sheath diameter (ONSD) is an easy and reliable tool for ICP monitoring.

The standard treatment for cholelithiasis is laparoscopic cholecystectomy, which is one of the most common surgical procedures. Laparoscopic hernia surgery has become increasingly popular. The use of laparoscopic techniques has expanded, particularly in treating inguinal hernias. Methods include trans-abdominal pre-peritoneal (TAPP), total extraperitoneal (TEP), and intra-peritoneal onlay mesh (IPOM). TAPP and IPOM are transperitoneal, whereas TEP is extraperitoneal. Transperitoneal repairs require direct insufflation of the peritoneum. In extraperitoneal procedures, the hernia is treated without entering the peritoneum, where the intraperitoneal organs are located. In these procedures, the peritoneum prevents the carbon dioxide (CO_2) gas administered for insufflation from entering the intraabdominal space entirely. Other common extraperitoneal procedures include prostatectomy, adenomectomy, and para-aortic lymph node dissections[9].

It has been reported in numerous studies[10-12] that ICP rises as a result of intraperitoneal laparoscopic surgery. Ultrasonographic assessment of ONSD is a well-established, easy, reliable, and non-invasive method for measuring intraocular pressure. According to meta-analyses[5,13] on this topic, an increase in ICP during laparoscopy is associated with a significant increase in ONSD in the early (0-30 minutes) and late (30-120 minutes) periods of CO_2 pneumoperitoneum. Patterson et al[14] determined that ONSD values of more than 5.8 mm were significant. Values greater than 5.8 mm indicate an ICP exceeding 20 mmHg.

In some studies[13,15], CO_2 absorption is greater during extraperitoneal laparoscopic surgery. Consequently, hypercarbia and cardiac arrhythmias may occur more frequently after these surgical procedures[15]. In contrast, studies[16,17] indicate that the rate of CO_2 absorption in extraperitoneal surgery is comparable to that of intraperitoneal but at a slower rate. However, the effect of extraperitoneal laparoscopic procedures on the central nervous system remains uncertain. We could not find any research comparing the effects of extraperitoneal and transperitoneal laparoscopic procedures on ICP. Laparoscopic total extraperitoneal (TEP) repair is the most common extraperitoneal laparoscopic procedure.

The purpose of this study was to compare the connection of ICP and transperitoneal laparoscopic cholecystectomy and extraperitoneal TEP inguinal hernia repair. The second objective was to assess the impact of operative time and CO_2 on ICP measurements.

Patients and Methods

Trial Design

This prospective study was conducted at the Health Sciences University Konya City Hospital Department of General Surgery, Turkey. Health Sciences University Ankara City Hospital Clinical Research Ethics Committee approval was obtained (Decision Number: E1-22-2852, Date: 09.21.2022), and all subjects provided written informed consent. This research procedure was developed following CONSORT recommendations[18]. This investigation was registered with ClinicalTrials.gov (NCT05668208). All techniques performed on human volunteers in studies conformed to the ethical norms of the Institutional Research Committee and the 1964 Helsinki Statement and its later revisions or other comparable ethical standards.

Participants and Eligibility Criteria

The study included 60 patients, 30 underwent laparoscopic cholecystectomy, and 30 underwent TEP inguinal hernia repair between 10.01.2022 and 10.31.2022.

Inclusion criteria were 18-70 years old, American Society of Anesthesiologists (ASA) I-II, and undergoing laparoscopic cholecystectomy (LV) with symptomatic cholelithiasis or TEP due to inguinal hernia value (HV).

Patients who converted to an open procedure, had glaucoma, ocular disease, history of eye procedures, cerebrovascular events, neurological disease, chronic kidney disease, or liver cirrhosis, and patients whose peritoneum was opened during TEP were excluded from the study.

Anesthesia Procedure

All patients received propofol 2 mg/kg and fentanyl 2 g/kg intravenously (IV) for analgesia while under general anesthesia. After 3 min of injecting 0.1 mg/kg rocuronium, endotracheal

intubation was performed. Propofol was used to maintain anesthesia with an oxygen-to-air ratio of 50:50. At induction, 4 mg dexamethasone was administered to prevent postoperative nausea and vomiting. As needed, intermittent dosages of fentanyl and rocuronium were administered. After the procedure, the patient was extubated after neuromuscular palsy was reversed with 0.05 mg/kg neostigmine and 0.02 mg/kg glycopyrrolate injection.

Surgical Method in Patients Undergoing Laparoscopic Cholecystectomy

A 10 mm camera port was inserted into the abdomen through a small incision created inferior to the umbilicus. Furthermore, CO_2 was used to produce pneumoperitoneum. The IAP was maintained at 14 mmHg. One 10 mm trocar in the subxiphoid area and two other 5 mm trocars in the subcostal area were inserted under camera visualization. The triangle of Callot was exposed and the cystic artery and duct were clipped and cut. The gallbladder was detached from the liver bed and removed from the abdomen. The abdominal CO_2 was released, and the trocars were withdrawn. The fascial defect and skin were closed, and the procedure was completed.

Surgical Method in Patients Undergoing Total Extraperitoneal (TEP) Repair

The external sheath of the rectus muscle was visualized with a small incision through the skin and subcutaneous tissue at the margin of the umbilicus. A 10 mm camera port was inserted into the preperitoneum, and CO_2 insufflation was started. The pressure was set at 14 mmHg. Under camera visualization, two additional 5 mm trocars were inserted into the preperitoneum between the umbilicus and the symphysis pubis. Laparoscopic dissectors and grasped were used to dissect the preperitoneal inguinal region. First, the hernia sac was separated, then a 10 × 15 cm prolene mesh was fixed to cover the femoral, direct, and indirect hernia areas. The trocars were removed, and the CO_2 released. The skin was closed, and the procedure was completed.

ONSD Measurement

ONSD was measured using transorbital sonography by two investigators blind to the study methodology. An E-CUBE i7 ultrasound device (mechanical index, 0.2; thermal index, 0) with a linear 6-13 Hz probe was used for transorbital sonography (Alpinion Medical Systems, Seoul, South Korea). A sterile occlusion gel was applied to avoid eye injury, and the eyelid was softly probed without applying pressure. The field was imaged ultrasonographically at the optic nerve level, and the ONSD picture was captured 3 mm behind the optic nerve head. The ONSD was measured in both eyes at three different times: before surgery (T0), during insufflation (T1), and after surgery (T2). ONSD was calculated as the mean of three readings. Heart rate (HR), non-invasive blood pressure (NIBP), oxygen saturation (SPO_2), and end-tidal CO_2 were also measured independently at each time point.

Statistical Analysis

The primary endpoint of our research was to compare the outcomes of extraperitoneal *vs.* intraperitoneal laparoscopic procedures on ONSD. For clinically valid results, at least 30 participants in each group needed a change of 0.3 mm in ONSD measurement. We computed the sample size based on the results of a pilot research project. Multivariate observational analysis was used on the data. For latent variables, descriptive statistics are provided. Mean and standard deviation are provided for continuous values, whereas frequency and percent are provided for categorical variables. For fixed factors, mixed-effect models were developed. We looked at the group, time, and group-time interaction. To compare continuous variables between the two groups, the *t*-test was used. We used bivariate correlation analysis to compare the values for ONSD among the three measurements. Least squares means were compared when the group-time interaction was significant. The SPSS Statistics program [Statistics for Windows, Version 20.0. (IBM Corp., Armonk, NY, USA)] was employed for data analysis. A *p*-value of 0.05 was regarded as significant.

Results

Sixty-one patients who applied to the department of general surgery for TEP inguinal hernia repair or laparoscopic cholecystectomy were assessed, and 52 of them were included in the study. Nine patients were excluded from the study, of which five patients did not accept consent forms and four had neurological diseases. Thus, 52 patients included in the study had ONSD, demographic data, ASA scores, and hemodynamic variables recorded.

Table I. Demographic variables and operation time.

Parameters	Group (n: 52)	Mean	Std. Deviation	*p*-value
Age	HV	49.54	13.491	0.370
	LV	46.15	13.511	
ASA scores	HV	-	-	0.412
	LV	-	-	
Weight	HV	81.50	7.027	0.643
	LV	80.54	7.829	
Gender	HV	-	-	0.001*
	LV	-	-	
Height	HV	167.77	5.908	0.04
	LV	172.27	4.729	
Optime	HV	90.7692	24.97408	0.026
	LV	77.3846	15.96766	

ASA: American Society of Anesthesiologists; HV: inguinal hernia value; LV: laparoscopic cholecystectomy value. *p-value lower than 0.001.

There was no significant difference between the two groups in terms of patient age, ASA score, and weight. There was a significant difference between the two groups in regard to gender and height ($p < 0.001$). There was a significant difference between the two groups in regard to operative time ($p = 0.026$) (Table I).

The ONSD at the T1 and T2 time points was significantly higher in the LV group ($p < 0.001$) (Figure 1). The ONSD measurements reached a maximum level at T1 in both groups. The degree of change between T0 and other measurement times was significantly different in each group, especially for T0 and T1. The Pearson correlation r value between the T0 and T1 values was 0.244 for right eyes and 0.794 for left eyes (results of the analysis are shown in Table II, Table III, and Figure 1). None of the patients had any complications after the procedures.

As for secondary outcomes, there were no significant differences between the two groups in terms of heart rate, mean arterial pressure, and SPO_2 during the basal, intraoperative, and postoperative periods. However, there was a significant difference between the two groups in terms of end-tidal CO_2 during the intraoperative and postoperative periods ($p = 0.027$ and 0.034). In addition, the end-tidal CO_2 values were significantly higher in the LV group (Figure 2).

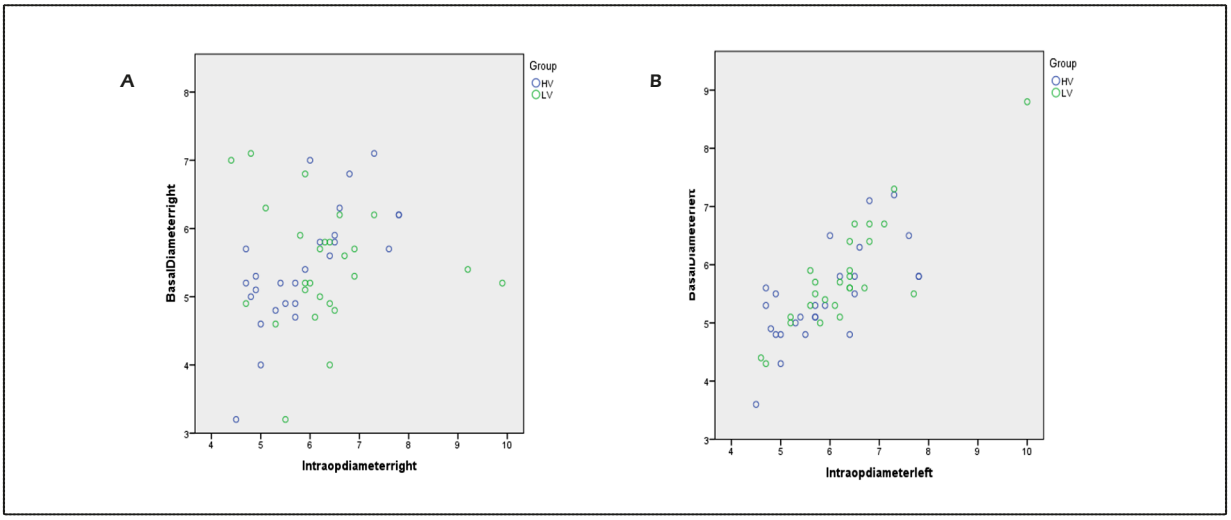

Figure 1. A, Correlation between right eyes basal and intraoperative diameters for HV and LV group. **B**, Correlation between left eyes basal and intraoperative diameters for HV and LV group.

Table II. Optic Nerve Sheath Diameter (ONSD) for the right eyes.

Parameters	Group (n: 52)	Mean	Std. Deviation	*p*-value
Basal diameter right	HV	5.45	0.881	1.0
	LV	5.45	0.881	
Intraop diameter right	HV	5.89	1.000	0.210
	LV	6.28	1.196	
Postop diameter right	HV	5.63	1.032	
	LV	6.09	1.296	0.169

HV: inguinal hernia value; LV: laparoscopic cholecystectomy value.

Table III. Optic Nerve Sheath Diameter (ONSD) for the left eyes.

Parameters	Group (n: 52)	Mean	Std. Deviation	*p*-value
Basal diameter left	HV	5.45	0.815	0.156
	LV	5.80	0.935	
Intraop diameter left	HV	5.89	1.000	0.176
	LV	6.28	1.060	
Postop diameter left	HV	5.47	0.911	0.104
	LV	5.95	1.138	

HV: inguinal hernia value; LV: laparoscopic cholecystectomy value.

Discussion

Laparoscopy is commonly used in various general surgery procedures, including cholecystectomy, colorectal surgery, gastric surgery, splenectomy, adrenalectomy, and hernia repair. The most significant advantage of laparoscopy is that patients recover rapidly and may return to regular life considerably sooner. In our study, we found that there was a significant difference, particularly for basal and intraoperative ONSD values between the HV and LV groups. Furthermore, despite the long operative time, ONSD values for the HV group were less than those for the LV group.

Unfortunately, certain negative effects may occur in all systems, particularly the respiratory, cardiac, urinary, and neurological systems. Fortunately, the majority of them improve postoperatively[19].

While neurological issues are uncommon, they can be significant. These issues vary from minor

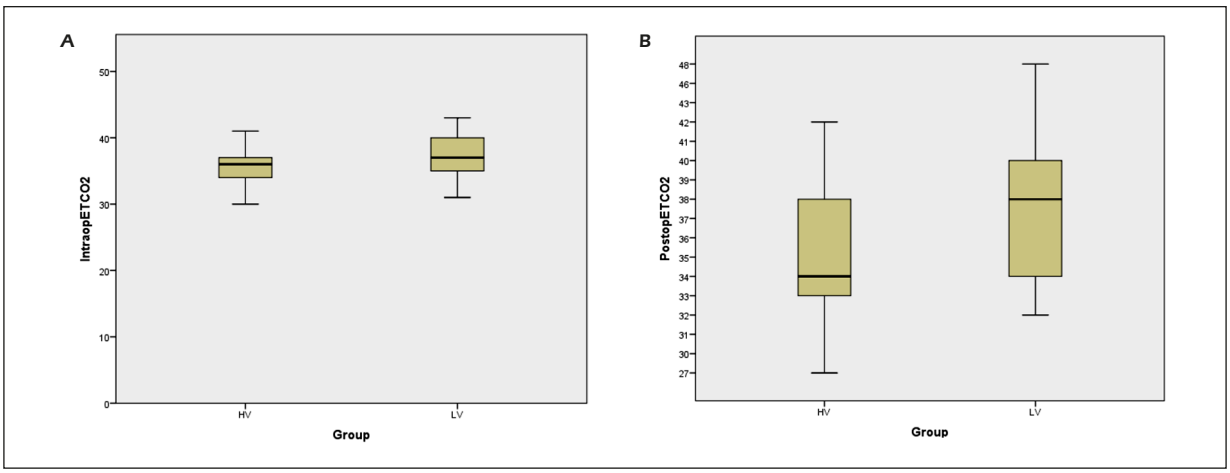

Figure 2. Intraoperative (**A**) and postoperative (**B**) end-tidal carbon dioxide between HV and LV groups.

headaches to ischemia issues that necessitate long-term intensive care support[11,20]. Increased ICP is the most critical mechanism in the development of neurological problems. One of the current studies[21] has found a link between CO_2 pneumoperitoneum and elevated ICP.

Therefore, it is critical to monitor ICP during a procedure. They may be invasive or non-invasive. Because of its invasiveness and potential complications, direct intraoperative monitoring of ICP is typically not suggested. Non-invasive procedures are becoming increasingly popular. Transcranial doppler (TCD), tympanic membrane displacement, near-infrared spectroscopy, and ONSD are a few examples[22,23]. ONSD is the most favorable among these approaches since it is simple, affordable, and may be used intraoperatively. Furthermore, a meta-analysis concluded that ONSD assessment might be employed as a follow-up approach, particularly in individuals at risk of elevated ICP[13]. Previous research[24] has found an increase in ONSD during intraperitoneal laparoscopic procedures. However, no research has been conducted to determine how ICP is influenced during extraperitoneal laparoscopic operations in which the peritoneum is not directly entered. As a result, the purpose of this study was to compare ONSD, an indirect indication of ICP, in extraperitoneal laparoscopic procedures and intraperitoneal laparoscopic procedures. During the procedure, the ONSD values in both groups reached their greatest levels, as predicted (T1). This demonstrates that, as indicated in the literature[24], ICP rises with insufflation.

Some authors[17] have observed increased peritoneal CO_2 absorption following extraperitoneal procedures, whereas others reported no change[25]. It is unclear how much CO_2 enters the intraperitoneal space through the peritoneum and how much is absorbed during these procedures. In measurements taken during the procedure (T1) and after the operation (T2), after the CO_2 gas was released, the ONSD value was greater in the intraperitoneal group than in the other group. This shows that ICP in extraperitoneal laparoscopic procedures may not increase as much as in intraperitoneal procedures. The degree of change between T0 and other measurement intervals varied considerably between groups (results of the post hoc analysis are shown in Table II, Table III, and Figure 1).

No problems were linked to ONSD measurement or surgical procedures in any of the patients. This supports the opinion that ONSD, the most widely used non-invasive approach, is dependable, as indicated in the literature[22,23].

Hypercarbia occurs during laparoscopic procedures due to CO_2 deposition in the tissues and circulatory system. In most individuals, this condition improves throughout the postoperative period and does not cause further complications. However, in circumstances where hypercarbia reaches extremely high levels, as well as in individuals with significant ventilation-perfusion issues, this might have devastating repercussions. Therefore, it is suggested that these individuals have their $PaCO_2$ and $PETCO_2$ levels properly monitored throughout the procedure. In addition, many studies[26,27] have found that end-tidal CO_2 levels are elevated after long-term laparoscopic procedures (particularly colorectal and gastric procedures). This has also been observed to be higher in laparoscopic cholecystectomy[27]. According to the literature, this value was greater in the transperitoneal group who underwent cholecystectomy in our study. In other words, the rise in end-tidal CO_2 levels after extraperitoneal laparoscopic procedures is not as great as in the transperitoneal group. In our study, the end-tidal CO_2 level was found to be higher in the transperitoneal group that underwent cholecystectomy compared to the extraperitoneal group, which is comparable with the literature[28,29].

One of the study's most significant limitations was the inclusion of participants of various ages, heights, weights, and comorbidities. We believe that research involving more homogeneous groups of patients with comparable features will be more reliable.

Another research limitation is the variation in operative time between the two groups. However, we believe that laparoscopic cholecystectomy takes less time because it is a common surgical technique.

Conclusions

During laparoscopic procedures, whether transperitoneal or extraperitoneal, ICP may rise. Due to our study, considering the low CO_2 value and low ICP, we have concluded that it is more advantageous to choose the laparoscopic extraperitoneal surgical technique, such as laparoscopic inguinal hernia repair. Therefore, more studies with large sample sizes are needed to reach a more definite conclusion.

Conflict of Interest
The Authors declare that they have no conflict of interests.

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Ethics Approval
Ethics approval was obtained by the Health Sciences University Ankara, City Hospital Clinical Research Ethics Committee (Decision Number: E1-22-2852, Date: 09.21.2022).

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