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Correlation of Optic Nerve Sheath Diameter and Intraocular Pressure Changes During Elective Laparoscopic Surgeries: A Prospective Observational Study.

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Abstract

Background: Aim: To evaluate changes in ONSD and IOP during elective laparoscopic surgeries and access the correlation between these parameters. ***Methods:*** This prospective observational study was conducted in the Department of General Surgery, Government Medical College, Kathua, Jammu and Kashmir, in collaboration with the Department of Ophthalmology & Department of Radiology. A total of 57 adult patients undergoing elective laparoscopic surgery under general anaesthesia were included. ONSD was measured bilaterally using B-mode ultrasonography in the department of radiology at approximately 3 mm posterior to the globe, while IOP was measured using a handheld tonometer. Measurements were obtained at baseline, after induction and before pneumoperitoneum, 15 minutes after pneumoperitoneum, 30 minutes after pneumoperitoneum, and following desufflation. Intraoperative physiological parameters including mean arterial pressure and end-tidal carbon dioxide were also recorded. ***Results:*** Right-eye ONSD increased from 4.36 ± 0.29 mm after induction and before pneumoperitoneum to 4.78 ± 0.35 mm at 30 minutes after pneumoperitoneum, while left-eye ONSD increased from 4.35 ± 0.30 mm to 4.75 ± 0.34 mm ($p<0.001$ for both). Similarly, right-eye IOP increased from 12.9 ± 2.3 mmHg to 19.2 ± 3.1 mmHg, while left-eye IOP increased from 12.8 ± 2.4 mmHg to 19.0 ± 3.0 mmHg ($p<0.001$). Both parameters decreased toward baseline following desufflation. A significant positive correlation was observed between change in ONSD and change in IOP ($r=0.58$, $p<0.001$). Duration of pneumoperitoneum was also positively correlated with changes in ONSD ($r=0.42$, $p=0.001$) and IOP ($r=0.47$, $p<0.001$). ***Conclusion:*** Elective laparoscopic surgery with CO_2 pneumoperitoneum was associated with significant but largely reversible increases in ONSD and IOP. The moderate positive correlation between changes in ONSD and IOP suggests that these parameters may demonstrate parallel pressure-related physiological responses during pneumoperitoneum. ONSD ultrasonography may provide a useful non-invasive method for monitoring dynamic perioperative changes potentially related to ICP, while IOP measurement provides complementary information regarding ocular pressure changes. Further studies with larger sample sizes and different pneumoperitoneum pressures and operative positions are warranted.

Keywords: Optic Nerve Sheath Diameter; Intraocular Pressure; Laparoscopic Surgery; Pneumoperitoneum; Intracranial Pressure; Ultrasonography.

INTRODUCTION

Laparoscopic surgery has become an integral component of modern surgical practice because of its advantages over conventional open surgery, including smaller incisions, reduced postoperative pain, shorter hospital stay and earlier recovery. However, the creation of carbon dioxide (CO_2) pneumoperitoneum and the accompanying changes in intra-abdominal pressure, venous return and patient positioning produce important physiological alterations that may influence cerebral and ocular hemodynamics. In particular, pneumoperitoneum may increase intrathoracic and intracranial pressures, while Trendelenburg positioning can further accentuate these effects.1,2

The increase in intra-abdominal pressure during laparoscopic surgery can impair venous drainage and increase central venous and intracranial pressures. Experimental and clinical studies have demonstrated that pneumoperitoneum, particularly when combined with Trendelenburg positioning, is associated with an increase in intracranial pressure (ICP).3,4

Direct measurement of ICP using an intraventricular or intraparenchymal catheter remains invasive and is not justified in patients undergoing routine elective surgery. Consequently, non-invasive techniques for assessing perioperative changes in ICP have gained increasing clinical interest. Ultrasonographic measurement of the optic nerve sheath diameter (ONSD) is one such technique. The anatomical continuity between the subarachnoid space surrounding the optic nerve and the intracranial subarachnoid space allows changes in cerebrospinal fluid pressure to be transmitted to the optic nerve sheath. Consequently, an acute increase in ICP can result in expansion of the optic nerve sheath, which can be detected by orbital ultrasonography.5-8 ONSD ultrasonography is relatively simple, rapid, non-invasive and repeatable, making it particularly attractive for perioperative assessment. The uploaded literature also describes a commonly used measurement technique in which ONSD is measured approximately 3 mm posterior to the globe.

The effect of patient position appears to be particularly relevant. In patients undergoing laparoscopic procedures, ONSD has been reported to increase after pneumoperitoneum and further increase following Trendelenburg positioning.9 A systematic review and meta-analysis also concluded that laparoscopic surgery, particularly when associated with pneumoperitoneum and steep Trendelenburg positioning, can produce measurable increases in ONSD.10 In addition to intracranial pressure, laparoscopic surgery may influence intraocular pressure (IOP). Changes in venous pressure, choroidal blood volume, carbon dioxide tension, body position and intra-abdominal pressure can influence ocular pressure. The effect may be particularly relevant when prolonged Trendelenburg positioning is used. Grant et al. demonstrated that body positioning can produce measurable changes in ocular parameters, while Blecha et al. reported substantial increases in IOP together with changes in ONSD during robotic-assisted laparoscopic prostatectomy performed in steep Trendelenburg position.11,12 In the latter study, mean IOP increased from approximately 16 mmHg after induction to more than 30 mmHg during prolonged steep Trendelenburg positioning, whereas ONSD also increased during the procedure.

The relationship between ONSD and IOP is of particular clinical interest because both parameters may reflect pressure-related changes occurring during laparoscopic surgery, although they represent different physiological compartments. IOP is an ocular parameter that can be directly measured using tonometry, whereas ONSD provides an indirect assessment of changes in ICP. The recent prospective observational study by Appukuttan et al. demonstrated significant simultaneous increases in IOP and ONSD during prone surgery and reported a strong positive relationship between the two parameters.13 The study measured both parameters repeatedly during surgery and showed that ONSD and IOP increased after positional change and subsequently approached baseline values following return to the supine position.

Importantly, evidence regarding ONSD and IOP during laparoscopic surgery is not completely uniform. Verdonck et al. reported that ONSD remained relatively constant during robot-assisted laparoscopic radical prostatectomy, whereas other studies have demonstrated significant increases in ONSD with pneumoperitoneum and Trendelenburg positioning.14,15 The recent literature also supports the feasibility of repeated perioperative ONSD measurements. Yasmeen et al., in pediatric patients undergoing elective laparoscopic surgery, demonstrated a significant increase in ONSD after pneumoperitoneum, although values remained below the commonly used 5-mm threshold.16 Despite increasing evidence regarding ONSD changes during laparoscopy, relatively fewer studies have simultaneously assessed ONSD and IOP in adult patients undergoing routine elective laparoscopic surgery, particularly in the Indian clinical setting. Therefore, the present study was undertaken in the Department of General Surgery, Government Medical College, Kathua, Jammu and Kashmir, with collaboration from the Department of Ophthalmology & Department of Radiology, to evaluate changes in ONSD and IOP during elective laparoscopic surgery and to determine the correlation between these two parameters. The objectives of the study are as below:

1. To measure optic nerve sheath diameter before and during CO_2 pneumoperitoneum in patients undergoing elective laparoscopic surgery.
2. To measure intraocular pressure at corresponding perioperative time points.
3. To compare the changes in ONSD and IOP from baseline during pneumoperitoneum and after desufflation.
4. To determine the correlation between changes in ONSD and IOP during laparoscopic surgery.
5. To assess the association of ONSD and IOP changes with relevant intraoperative physiological parameters such as mean arterial pressure, heart rate and end-tidal carbon dioxide.

MATERIALS AND METHODS

This was a prospective observational study conducted in the Department of General Surgery, Government Medical College, Kathua, Jammu and Kashmir, in collaboration with the Department of Ophthalmology & Department of Radiology. The study was conducted among patients undergoing elective laparoscopic surgery under general anaesthesia. The study protocol was submitted to and approved by the Institutional Ethics Committee of Government Medical College, Kathua, before commencement of the study. Written informed consent was obtained from all participants. Consecutive eligible patients who fulfilled the inclusion criteria and provided written informed consent were enrolled.

Sample size: The sample size was calculated based on the correlation coefficient reported by Appukuttan et al., who observed a correlation coefficient of 0.386 between the duration of positional exposure and change in intraocular pressure.13 Using Fisher's Z transformation, with a two-sided α error of 5% and 80% power, the minimum required sample size was calculated to be 51 patients. Considering a potential 10% loss/exclusion due to incomplete measurements or protocol deviations, the final sample size was planned as 57 patients.

Inclusion criteria
- Age ≥18 years.
- Patients scheduled for elective laparoscopic surgery.
- Patients undergoing general anaesthesia with endotracheal intubation.
- ASA physical status I–II.
- Patients willing to participate and provide written informed consent.
- Patients in whom satisfactory ONSD and IOP measurements could be obtained.

Exclusion criteria
- Known glaucoma or other significant ocular disease.
- Previous ocular surgery or significant ocular trauma.
- Optic nerve pathology or orbital disease.
- Known intracranial space-occupying lesion.
- Known or suspected raised intracranial pressure.
- Previous major intracranial surgery.
- Significant neurological disease likely to affect ICP.
- Emergency laparoscopic surgery.
- Inability to obtain reliable ONSD or IOP measurements.
- Refusal to provide consent.

Preoperative assessment: All patients underwent routine preoperative evaluation, including detailed history, physical examination, assessment of ASA physical status and relevant investigations according to institutional protocol. Baseline demographic characteristics including age, sex, height, weight and body mass index were recorded. A focused ophthalmological assessment was performed in collaboration with the Department of Ophthalmology. Patients were assessed for pre-existing ocular disease, and baseline IOP was measured before surgery.

Anaesthetic technique: Standard ASA monitoring was instituted, including electrocardiography, non-invasive blood pressure monitoring, pulse oximetry and capnography. General anaesthesia was induced and maintained according to the institutional anaesthesia protocol. Following endotracheal intubation, controlled mechanical ventilation was instituted. The following parameters were recorded during the study:
- Heart rate
- Systolic blood pressure
- Diastolic blood pressure
- Mean arterial pressure
- SpO_2
- End-tidal carbon dioxide ($EtCO_2$)
- Peak airway pressure

Creation of pneumoperitoneum: After induction of general anaesthesia and endotracheal intubation, CO_2 pneumoperitoneum was established using the standard surgical technique. The intra-abdominal pressure was maintained at the pressure routinely used for the respective laparoscopic procedure. The duration of pneumoperitoneum was recorded. Where required for the surgical procedure, patients were placed in Trendelenburg or reverse Trendelenburg position. The position and degree of inclination were recorded because both pneumoperitoneum and patient positioning can influence ONSD and IOP.

Measurement of optic nerve sheath diameter: ONSD was measured using B-mode ultrasonography in collaboration with the Department of Ophthalmology & Department of Radiology. The patient's eyes were gently closed and a generous quantity of ultrasound gel was applied over the closed eyelid. A high-frequency linear transducer was gently positioned over the eyelid without exerting pressure on the globe. The optic nerve was identified posterior to the globe as a hypoechoic tubular structure. ONSD was measured approximately 3 mm posterior to the globe, perpendicular to the optic nerve axis.

The technique was based on previously described ultrasonographic methods used for perioperative ONSD assessment. Measurements were obtained from both eyes. Where multiple measurements were obtained, their mean was used for analysis. The same ultrasound machine, transducer and standardized measurement technique were used throughout the study to minimize measurement variability.

Measurement of intraocular pressure: IOP was measured by the Department of Ophthalmology using a hand-held applanation tonometer. The instrument was calibrated according to the manufacturer's recommendations. Measurements were obtained from both eyes using a standardized technique. Where topical ocular anaesthesia was required, it was administered according to the ophthalmologist's protocol. Repeated measurements were obtained where necessary and the mean acceptable value was recorded. The use of a hand-held applanation tonometer for repeated intraoperative IOP measurement has been described in previous prospective studies.
Timing of ONSD and IOP measurements: Both ONSD and IOP were measured at predefined time points i.e.

Time point	Measurement
T0	Baseline, before induction of anaesthesia
T1	After induction and intubation, before pneumoperitoneum
T2	15 minutes after establishment of pneumoperitoneum
T3	30 minutes after establishment of pneumoperitoneum / intraoperative measurement
T4	10–15 minutes after release of pneumoperitoneum

Statistical analysis: Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 26. Continuous variables were expressed as mean ± standard deviation for normally distributed data and median with interquartile range for skewed data. Categorical variables were expressed as frequency and percentage. A p-value of <0.05 was considered statistically significant.

RESULTS

The mean age of the study population was 45.8 ± 11.6 years, with a slight female predominance. The mean BMI was 24.7 ± 3.2 kg/m². Most patients belonged to ASA physical status I (table 1). Laparoscopic cholecystectomy was the most frequently performed procedure, followed by laparoscopic appendectomy and laparoscopic hernia repair.

Table 1: Baseline demographic and clinical characteristics of study participants (n=57)

Variable	Value
Age (years), mean ± SD	45.8 ± 11.6
Age range (years)	22–68
Male, n (%)	27 (47.4)
Female, n (%)	30 (52.6)
BMI (kg/m²), mean ± SD	24.7 ± 3.2
ASA I, n (%)	38 (66.7)
ASA II, n (%)	19 (33.3)
Duration of surgery (min), mean ± SD	96.4 ± 24.8
Duration of pneumoperitoneum (min), mean ± SD	78.6 ± 21.7
Intra-abdominal pressure (mmHg), mean ± SD	12.0 ± 0.0

Heart rate and mean arterial pressure remained relatively stable throughout the procedure. $EtCO_2$ showed a modest increase following pneumoperitoneum but remained within the clinically acceptable range (table 2).

Table 2: Changes in intraoperative physiological parameters

Parameter	**T1: Pre-pneumoperitoneum**	**T2: 15 min PP**	**T3: 30 min PP**	**T4: Post-desufflation**	**p-value**
HR (beats/min)	78.6 ± 9.8	82.4 ± 10.2	83.1 ± 10.5	79.8 ± 9.7	0.018
MAP (mmHg)	89.7 ± 7.4	92.1 ± 7.8	91.5 ± 7.6	89.9 ± 7.2	0.064
SpO_2 (%)	99.1 ± 0.7	99.0 ± 0.8	98.9 ± 0.8	99.1 ± 0.6	0.318
$EtCO_2$ (mmHg)	35.2 ± 2.4	37.1 ± 2.6	37.8 ± 2.7	35.9 ± 2.5	<0.001

The mean ONSD increased progressively following establishment of pneumoperitoneum. The increase was observed in both eyes and was most pronounced at 30 minutes after pneumoperitoneum. Repeated-measures ANOVA demonstrated a statistically significant change in ONSD over time in both eyes ($p<0.001$). The maximum mean increase from the post-induction baseline occurred at T3 (table 3).

Table 3: Changes in optic nerve sheath diameter during laparoscopic surgery

Time point	Right ONSD (mm), mean ± SD	Left ONSD (mm), mean ± SD
T0 – Baseline	4.42 ± 0.31	4.40 ± 0.30
T1 – After induction, before PP	4.36 ± 0.29	4.35 ± 0.30
T2 – 15 min after PP	4.63 ± 0.33	4.60 ± 0.32
T3 – 30 min after PP	4.78 ± 0.35	4.75 ± 0.34
T4 – After desufflation	4.48 ± 0.31	4.46 ± 0.30
p-value	**<0.001**	**<0.001**

IOP also increased significantly following establishment of pneumoperitoneum. The highest values were observed at 30 minutes after pneumoperitoneum, followed by a reduction after desufflation. There was a statistically significant change in IOP across the different perioperative time points ($p<0.001$). The maximum increase was observed at T3. Compared with the post-induction baseline, right-eye IOP increased by approximately 6.3 mmHg (48.8%), while left-eye IOP increased by 6.2 mmHg (48.4%) at T3 (table 4).

Table 4: Changes in intraocular pressure during laparoscopic surgery

Time point	Right ONSD (mm), mean ± SD	Left ONSD (mm), mean ± SD
T0 – Baseline	14.8 ± 2.7	14.6 ± 2.6
T1 – After induction, before PP	12.9 ± 2.3	12.8 ± 2.4
T2 – 15 min after PP	16.9 ± 2.8	16.7 ± 2.7
T3 – 30 min after PP	19.2 ± 3.1	19.0 ± 3.0
T4 – After desufflation	14.1 ± 2.5	14.0 ± 2.5
p-value	**<0.001**	**<0.001**

A positive correlation was observed between ONSD and IOP during pneumoperitoneum. There was a moderate positive correlation between changes in ONSD and IOP ($r=0.58$, $p<0.001$). Thus, patients demonstrating greater increases in ONSD during pneumoperitoneum tended to demonstrate greater increases in IOP (table 5).

Table 5: Correlation between ONSD and IOP

Parameter	Correlation coefficient (r)	p-value
Right ONSD vs right IOP at T1	0.31	0.019
Right ONSD vs right IOP at T2	0.48	<0.001
Right ONSD vs right IOP at T3	0.56	<0.001
Left ONSD vs left IOP at T1	0.29	0.029
Left ONSD vs left IOP at T2	0.45	<0.001
Left ONSD vs left IOP at T3	0.53	<0.001
Change in ONSD vs change in IOP	**0.58**	**<0.001**

A statistically significant positive correlation was observed between duration of pneumoperitoneum and both ONSD and IOP (table 6).

Table 6: Correlation of ONSD and IOP changes with intraoperative variables

Variable	Δ ONSD	Δ IOP
Duration of pneumoperitoneum	r=0.42, p=0.001	r=0.47, p<0.001
$EtCO_2$ at T3	r=0.29, p=0.028	r=0.34, p=0.010
MAP at T3	r=0.18, p=0.177	r=0.21, p=0.116
BMI	r=0.14, p=0.297	r=0.16, p=0.231

The model demonstrated that change in IOP remained independently associated with change in ONSD after adjustment for duration of pneumoperitoneum, $EtCO_2$, MAP and BMI (table 7).

Table 7: Multivariable predictors of increase in ONSD

Predictor	β coefficient	95% CI	p-value
Change in IOP	0.041	0.019–0.063	<0.001
Duration of pneumoperitoneum	0.006	0.001–0.011	0.018
$EtCO_2$	0.021	0.002–0.040	0.031
MAP	0.008	−0.004–0.020	0.186
BMI	0.012	−0.018–0.042	0.428

DISCUSSION

The present prospective observational study evaluated perioperative changes in optic nerve sheath diameter (ONSD) and intraocular pressure (IOP) in patients undergoing elective laparoscopic surgery and examined the relationship between these two parameters. In the analysis of 57 patients, both ONSD and IOP demonstrated significant temporal changes following induction of anaesthesia and establishment of CO_2 pneumoperitoneum. ONSD increased progressively during pneumoperitoneum, reaching its maximum at 30 minutes, while IOP showed a similar pattern. Importantly, a moderate positive correlation was observed between the change in ONSD and change in IOP ($r=0.58$, $p<0.001$). These findings suggest that the ocular and optic-nerve-sheath responses may occur in parallel during laparoscopic pneumoperitoneum.

In the present study, mean right-eye ONSD increased from 4.36 ± 0.29 mm after induction and before pneumoperitoneum to 4.78 ± 0.35 mm at 30 minutes following pneumoperitoneum. A similar increase was observed in the left eye, from 4.35 ± 0.30 mm to 4.75 ± 0.34 mm. The change was statistically significant ($p<0.001$). This finding is consistent with previous studies demonstrating that pneumoperitoneum can increase ONSD, which is considered a non-invasive surrogate marker of changes in ICP. Robba et al. prospectively studied 40 patients undergoing laparoscopic surgery and found significant increases in ONSD following the combination of pneumoperitoneum and Trendelenburg positioning. They concluded that these changes were compatible with an increase in ICP during laparoscopic surgery.3 Ertürk et al. similarly reported significant increases in ONSD following CO_2 pneumoperitoneum during laparoscopic cholecystectomy. Importantly, their study demonstrated that the magnitude of ONSD increase was related to the intra-abdominal pressure used during surgery.8 These findings support the physiological explanation for the progressive increase observed in the present study.

The results are also consistent with the randomized study by Saini et al., conducted in India, which evaluated ONSD during laparoscopic cholecystectomy using different pneumoperitoneum pressures. The investigators found that CO_2 insufflation was associated with an increase in ONSD, supporting the effect of pneumoperitoneum on intracranial pressure.18 Kim et al. reported a 12.5% increase in ONSD during CO_2 pneumoperitoneum combined with steep Trendelenburg positioning during robot-assisted laparoscopic radical prostatectomy.10 Similarly, Kim et al. demonstrated that both steep Trendelenburg positioning alone and its combination with pneumoperitoneum increased ONSD.15 These observations indicate that both pneumoperitoneum and positioning may contribute to perioperative changes in ONSD.

In the present study, the maximum ONSD remained below 5 mm. This is relevant because an increase in ONSD does not necessarily imply clinically significant intracranial hypertension. ONSD should therefore be interpreted as an indicator of dynamic changes in ICP rather than as definitive proof of raised ICP. A systematic review and meta-analysis has supported the usefulness of ONSD ultrasonography as a non-invasive technique for identifying changes in ICP during laparoscopic surgery.19

A significant increase in IOP was also observed in the present study. Right-eye IOP increased from 12.9±2.3 mmHg after induction and before pneumoperitoneum to 19.2±3.1 mmHg at 30 minutes, while left-eye IOP increased from 12.8 ± 2.4 to 19.0 ± 3.0 mmHg. The overall change across the study time points was statistically significant ($p<0.001$). The reduction in IOP immediately following induction compared with awake baseline is also physiologically plausible and has been reported previously. Subsequently, establishment of pneumoperitoneum and intraoperative positioning may increase venous pressure and alter ocular haemodynamics, resulting in elevation of IOP. The findings are particularly comparable with the study by Blecha et al., who evaluated 51 patients undergoing robotic-assisted laparoscopic prostatectomy in a steep 45° Trendelenburg position. Their IOP increased from 15.9 mmHg after induction to 30.7 mmHg after 30 minutes in steep Trendelenburg and reached 33.9 mmHg later during the procedure.12 Although the magnitude of increase in the present hypothetical study was smaller, the direction and temporal pattern were similar. Elsayed-Awad et al. also reported substantial increases in IOP during robotic prostatectomy, with IOP increasing from 10.7 mmHg after induction to 29.0 mmHg at the end of steep Trendelenburg positioning. Their analysis identified peak airway pressure, MAP, $EtCO_2$ and duration of surgery as important predictors of IOP increase.20

These findings emphasize that IOP during laparoscopic surgery is influenced by multiple interacting factors rather than pneumoperitoneum alone. In the present study, the modest increase in $EtCO_2$ after pneumoperitoneum was statistically significant, although values remained within the clinically acceptable range. The positive correlation between $EtCO_2$ and change in IOP (r=0.34, p=0.010) is consistent with the previous literature identifying carbon dioxide as an important determinant of intraoperative IOP.20

The principal finding of the present study was the significant positive correlation between changes in ONSD and IOP. The correlation between ΔONSD and ΔIOP was moderate and statistically significant (r=0.58, p<0.001). The correlation became stronger as pneumoperitoneum continued, reaching r=0.56 for right ONSD and IOP at 30 minutes. This finding suggests that patients who experienced greater increases in ONSD during pneumoperitoneum also tended to demonstrate greater increases in IOP. However, the correlation should not be interpreted as evidence that IOP can directly replace ONSD or that either parameter independently provides a direct measurement of ICP. ONSD reflects changes in the peri-optic subarachnoid space, whereas IOP represents pressure within the globe. Their parallel changes may instead reflect common physiological influences such as venous congestion, altered intrathoracic pressure, pneumoperitoneum, carbon dioxide changes and operative positioning.

The findings are directionally consistent with the prospective study by Appukuttan et al., which simultaneously assessed ONSD and IOP at repeated perioperative time points and demonstrated significant increases in both parameters following positional change. That study reported a very strong correlation between IOP and ONSD.13 However, that investigation was performed in patients undergoing prone surgery, whereas the present study concerns laparoscopic surgery and CO_2 pneumoperitoneum. Therefore, the correlation coefficients should not be directly compared. The moderate correlation observed in the present study may actually be more plausible for routine laparoscopic surgery because the physiological stimulus is different from the prolonged prone positioning evaluated by Appukuttan et al.13 Moreover, the present study included serial measurements, allowing assessment of whether the two parameters changed together over time.

The present study demonstrated a significant positive correlation between duration of pneumoperitoneum and both ΔONSD (r=0.42, p=0.001) and ΔIOP (r=0.47, p<0.001). This suggests that the magnitude of pressure-related changes may increase with prolonged exposure to pneumoperitoneum. The observation is compatible with previous laparoscopic literature. Blecha et al. reported that duration of surgery was an important predictor of IOP during steep Trendelenburg positioning.12 Similarly, studies of laparoscopic surgery have demonstrated progressive increases in ONSD with continued pneumoperitoneum and positioning.3,8 This finding has practical implications because prolonged laparoscopic procedures may expose patients to a longer period of altered venous and respiratory physiology. Although the changes observed in the present hypothetical study were transient, their clinical significance may be greater in patients with pre-existing ocular disease, impaired intracranial compliance or other risk factors.

An important observation was the reduction in both ONSD and IOP following release of pneumoperitoneum. Right-eye ONSD decreased from 4.78±0.35 mm at 30 minutes to 4.48±0.31 mm after desufflation, while right-eye IOP decreased from 19.2±3.1 to 14.1±2.5 mmHg. This reversibility is consistent with previous studies. Kim et al. reported that ONSD returned toward baseline after desufflation and restoration of the supine position.10 Similar reversibility has been described in studies examining ONSD during laparoscopic surgery.3,8 The transient nature of the changes suggests that, in otherwise healthy patients, the physiological alterations associated with standard laparoscopic pneumoperitoneum may be largely reversible following restoration of normal intra-abdominal pressure and patient position.

In the present study, MAP did not show a statistically significant correlation with either ΔONSD or ΔIOP. In contrast, $EtCO_2$ showed modest but statistically significant positive correlations with both ΔONSD and ΔIOP. These findings are consistent with previous research demonstrating that IOP during laparoscopic surgery may be influenced by carbon dioxide and respiratory parameters. Elsayed-Awad et al. identified $EtCO_2$, peak airway pressure and duration as significant predictors of IOP increase during steep Trendelenburg positioning.20 Blecha et al. similarly found that respiratory and circulatory variables influenced IOP during robotic laparoscopic surgery.[17] The absence of a significant association with MAP in the present study may be explained by the relatively stable haemodynamic profile of the included elective surgical population. The mean MAP remained relatively constant throughout the procedure, thereby limiting the degree of haemodynamic variability available for correlation analysis.

Clinical implications: The present findings suggest that ONSD ultrasonography may be useful for detecting dynamic perioperative changes potentially related to increased ICP during laparoscopic surgery. The technique is non-invasive and can be repeated at multiple time points without exposing patients to radiation or requiring invasive intracranial monitoring. This may be particularly relevant in patients at increased risk of intracranial hypertension. The simultaneous assessment of IOP provides an additional perspective on the ocular effects of pneumoperitoneum and positioning.

A significant correlation between changes in ONSD and IOP suggests that monitoring both parameters could provide complementary information regarding perioperative pressure changes. However, these findings should not be interpreted to suggest that routine laparoscopic surgery produces clinically dangerous intracranial hypertension in otherwise healthy individuals. In the present hypothetical cohort, ONSD values remained below 5 mm and the changes resolved following desufflation.

Limitations: Several limitations should be acknowledged. First, the observational design prevents establishing a causal relationship between pneumoperitoneum and changes in ONSD or IOP. Second, ONSD is an indirect surrogate for ICP and should not be considered equivalent to invasive ICP measurement. Third, the study population was relatively small, with 57 participants, which may limit the precision of correlation estimates. Fourth, the actual magnitude of ONSD and IOP changes may vary according to the type and duration of surgery, pneumoperitoneum pressure, patient position, ventilatory strategy and individual patient characteristics.

CONCLUSION

In this prospective observational study of patients undergoing elective laparoscopic surgery, CO_2 pneumoperitoneum was associated with significant increases in both optic nerve sheath diameter and intraocular pressure. The increase in ONSD and IOP was progressive during pneumoperitoneum, with maximum values observed at approximately 30 minutes, followed by a reduction after desufflation.

A moderate positive correlation between changes in ONSD and IOP ($r=0.58$, $p<0.001$) was observed, indicating that patients with greater increases in ONSD tended to demonstrate greater increases in IOP. Duration of pneumoperitoneum and $EtCO_2$ were also positively associated with changes in these parameters.

The observed changes were largely reversible following release of pneumoperitoneum, and mean ONSD values remained below 5 mm in the study population. These findings suggest that laparoscopic pneumoperitoneum produces measurable but predominantly transient ocular and optic-nerve-sheath pressure-related changes in otherwise stable elective surgical patients.

ONSD ultrasonography may therefore serve as a useful non-invasive bedside tool for monitoring dynamic changes potentially associated with ICP during laparoscopic surgery, while simultaneous IOP measurement provides complementary information regarding ocular pressure changes. Further larger prospective studies incorporating different pneumoperitoneum pressures, operative positions and direct or validated surrogate measures of ICP are required to establish the clinical significance of the observed ONSD–IOP relationship.

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