Original Research Article

Exploring The Interplay: A Comparison Between Changes in Optic Nerve Sheath Diameter and End-Tidal Carbon Dioxide in Patients Undergoing Laparoscopic Surgery Under General Anaesthesia

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Abstract:

Laparoscopic surgeries offer multifaceted benefits over traditional open approaches. However, physiological alterations caused by CO_2 insufflation may have an impact on intracranial dynamics. Optic nerve sheath diameter (ONSD) is non-invasive indicator of intracranial pressure (ICP). This study analyses relationship between changes in end-tidal carbon dioxide ($EtCO_2$) and ONSD during laparoscopic procedures. **Methods**: A prospective observational study spanning duration of 1 year was carried on 40 ASA I/II patients aged 18-75, without pre-existing ophthalmic and neurological conditions, undergoing elective laparoscopic procedures. A high-resolution ultrasonography probe was used to quantify ONSD bilaterally at T1 (10 minutes after induction), T2 (30 minutes post-insufflation), T3 (10 minutes post-desufflation). $EtCO_2$, MAP and HR were simultaneously recorded at these intervals. Continuous variables expressed as mean ± SD, categorical variables as frequencies, percentages. Pearson's correlation and paired t-tests were used; p-values <0.05 deemed significant. **Results**: There were no significant changes in patient demographic data and procedure time. ONSD increased significantly at T2 (5.36±0.14 mm) compared to T1 (4.62±0.17 mm; r=0.86, p< 0.05). ONSD decreased significantly at T3 (5.03 ± 0.08 mm) but remained higher than baseline T1. $EtCO_2$ showed significant correlation with ONSD at T2 and T3 ($p < 0.05$). MAP and HR also increased significantly at T2 ($p < 0.05$). **Conclusion**: Changes in cerebral dynamics influenced by systemic hemodynamics and $EtCO_2$ are reflected in variations in ONSD during laparoscopic procedures. ONSD offers a reliable, non-invasive way to monitor intracranial pressure during laparoscopic procedures.

Keywords: CO_2 insufflation, End-tidal carbon dioxide ($EtCO_2$), Intracranial pressure (ICP), Laparoscopic surgery, Optic nerve sheath diameter (ONSD).

Introduction:

Today laparoscopic surgeries are performed extensively as they have significant advantages over the traditional open approaches. However, these come with their own share of disadvantages in the form of respiratory, cardiovascular, and central nervous system adverse effects. This is principally due to the inflation of the abdominal cavity with CO2 (insufflation).[1] Increase in ICP is one of the outcomes of this resultant pneumoperitoneum. This raised ICP is multifactorial. The pneumoperitoneum causes the peritoneal surface to absorb CO2, increasing arterial carbon dioxide partial pressure (PaCO2) and, in turn, intracranial pressure (ICP). Pneumoperitoneum raises intraabdominal pressure which is

transmitted to lumbar venous plexus causing impaired CSF drainage resulting in raised ICP. [2,3]

Invasive monitoring devices like an extra ventricular drain are the gold standard for measuring ICP, and they are associated with severe complications like haemorrhage, and infection. [4,5] Moreover, these invasive methods are exorbitant for routine laparoscopic procedures. Meanwhile, measuring the optic nerve sheath diameter by transbulbar sonography is an effective, simple, non-invasive, and replicable way for detection of alterations on ICP non-invasively. [6-8]

In Laparoscopy, absorption of CO_2 from the pneumoperitoneum into the bloodstream may lead to elevated $ETCO_2$ levels. This hypercapnia causes cerebral vasodilation, which in turn increases intracranial pressure (ICP).[1] Since ONSD serves as a non-invasive marker of ICP, changes in $ETCO_2$ can directly influence ONSD measurements. Increases in $ETCO_2$ may correlate with a rise in ONSD, reflecting the effects of hypercapnia on intracranial dynamics.[9] In healthy adults, normal ONSD is up to 5 mm measured through transorbital ultrasonography and it could be approximately 5.8 - 6.0 mm with magnetic resonance imaging. An ONSD greater than 5 mm in both eyes signifies an ICP greater than 20 mmHg.[10] **Aims and objectives:** The aim of this study is to assess how patients undergoing laparoscopic procedures under general anaesthesia alter their ONSD and ETCO2. The primary objective is to compare ONSD at different times of surgery and its correlation with ETCO2. The secondary objective is to correlate these measurements with hemodynamic changes.

Materials and methodology:

This prospective observational study comprised 40 ASA I and II patients, ages 18 to 75, who had laparoscopic procedures performed under general anaesthesia. Written informed permission was collected from participants and approved by the Institutional Ethical Committee. Patients with a BMI over 30 kg/m^2, patients who had severe heart diseases, diabetes, and hypertension with ocular and neurological complications, patients who had undergone ocular, neurological, thoracic, and abdominal surgeries, patients who had glaucoma, and patients with intracranial pathologies and hydrocephalus were excluded from this study.

On arrival in the operation theatre, standard multipara monitors like pulse-oximetry, non-invasive blood pressure, electrocardiography were applied. Patients were premedicated with glycopyrrolate and midazolam, dosages adjusted to body weight. General anaesthesia was induced with intravenous propofol 2 mg/kg and fentanyl 1.5 mcg/kg. For endotracheal intubation, vecuronium bromide 0.1 mg/kg intravenous bolus was used. General anaesthesia was maintained with a 1:1 mixture of oxygen and air, and isoflurane to achieve a MAC of 1.0 to 1.2. Volume controlled ventilation was given with a tidal volume of 6mL/kg, and PEEP of 5 cmH_2O. Respiratory rate was initially set to maintain end tidal carbon dioxide between 35 and 45 mmHg and no further adjustments were made. ONSD, EtCO2, NIBP, and HR were recorded 10 minutes after induction of anaesthesia. Prior to insufflation, the gastrointestinal system was decompressed using a nasogastric tube. CO2 pneumoperitoneum was achieved, and intra-abdominal pressure was set between 12-14 mmHg. The parameters were once again recorded 30 minutes after achieving pneumoperitoneum and 10 minutes after desufflation. Analgesia was provided with maintenance doses of fentanyl. IV ondansetron was administered to prevent postoperative nausea and vomiting. At the end of the surgery, patients who met the necessary extubation criteria were shifted to the recovery area after extubation.

ONSD measurements were performed under the guidance of a consultant with an experience of at least 30 ocular scans. Both eyes were covered with a Tegaderm patch, and a thick layer of conductive gel was applied over it. A linear ultrasonic probe with a high frequency (7.5–12 Hz)

was employed. Measurements were taken on the horizontal axis. An integrated digital calliper was used to measure the ONSD three millimetres posterior to the optic nerve's entry point into the globe. The distance between the hyperechoic nerve sheath and its hypoechoic outer borders was referred to as the ONSD. The final ONSD value at that time point was calculated statistically by averaging the two eyes. Data was compiled and analyzed using SPSS software version 27. Means and standard deviations were used to convey quantitative data, whereas percentages were used to express qualitative factors. A chi-squared or Fisher's exact test was employed for qualitative data, while a paired or unpaired t-test was employed for quantitative variables to analyze the difference between the two groups. Pearson's correlation coefficient was used to determine the relation between two quantitative variables. A significance level of 0.05 was established.

Results:

40 ASA I/II patients, ranging in age from 18 to 75, who were undergoing elective laparoscopic surgeries under general anaesthesia were examined in this study. The patients' average age was 39.17 ± 13.67 years, and the majority of participants were female (67.5%). There was no discernible change in the baseline demographics, and the operation and pneumoperitoneum took an average of 115.5 ± 19.86 and 82.75 ± 20.50 minutes, respectively. (Table 1)

Variables	Values
Male/Female	27 (67.5%) / 13 (32.5%)
Age (years)	39.17 (13.67)
BMI (kg/m2)	23.22 (2.90)
Duration of pneumoperitoneum	82.75 (20.50)
Duration of Surgery	115.5 (19.86)

Table 1: Demographic data and surgery information

Measurements of the optic nerve sheath diameter (ONSD) revealed notable variations over the course of the three time points. The ONSD was 4.62 ± 0.17 mm at baseline (T1). The ONSD dramatically increased to 5.36 ± 0.14 mm ($p < 0.001$) after insufflation (T2), indicating that CO2 pneumoperitoneum was the cause of the elevated ICP. After desufflation (T3), the ONSD decreased to 5.03 ± 0.08 mm; however, it remained significantly higher than the baseline ($p < 0.05$). This implies that there is an ongoing intracranial dynamic shift even after desufflation.

The elevated ONSD was highly correlated with the end-tidal carbon dioxide ($EtCO_2$) levels, which increased significantly from 37.28 ± 1.48 mmHg at T1 to 40.17 ± 1.76 mmHg at T2 ($p < 0.001$). At T3, $EtCO_2$ levels were somewhat higher than baseline but largely adjusted to 38.97 ± 1.66 mmHg. Hemodynamic measures like heart rate (HR) and mean arterial pressure (MAP) also showed notable increases at T2, going from 76.80 ± 5.23 bpm and 88.77 ± 5.99 mmHg at T1 to 80.72 ± 6.63 bpm and 95.63 ± 5.47 mmHg, respectively ($p < 0.05$). After the desufflation, these parameters reverted to their initial levels. According to the correlation analysis, there was a strong relationship between changes in ONSD and changes in $EtCO_2$, MAP, and HR, especially during pneumoperitoneum. (Table 2)

Variables	T1	T2	T3	P
ONSD (mm)	4.62 (0.17)	5.36 (0.14)	5.03 (0.08)	<0.001
ETCO2 (mmHg)	37.28 (1.48)	40.17 (1.76)	38.97 (1.66)	<0.001
HR	74.80 (5.23)	80.72 (6.63)	75.57 (4.96)	<0.05
MAP	88.77 (7.99)	95.63 (5.47)	93.18 (7.66)	<0.05

HR – Heart rate, MAP - Mean arterial pressure

Table 2: Optic nerve sheath diameter, end-tidal carbon dioxide, and hemodynamic parameters.

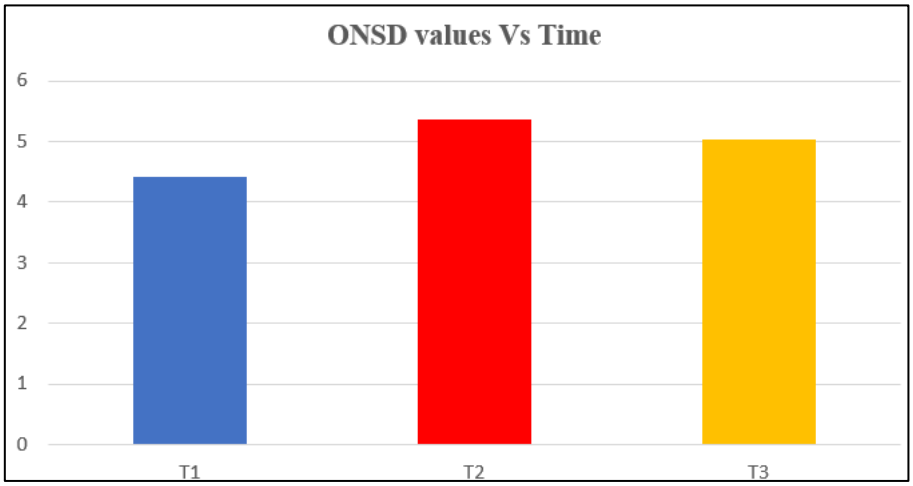

Fig 1: ONSD values at T1, T2 and T3

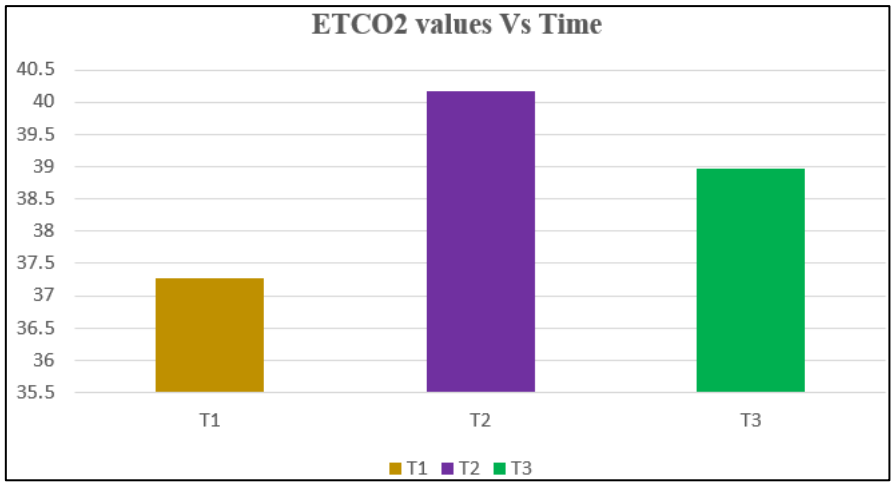

Fig 2: EtCO2 values at T1, T2 and T3

Discussion:

This study aims to observe whether there is an increase in ONSD and ETCO2 in patients undergoing laparoscopic surgeries. Results showed an increase in ONSD and ETCO2, in relation to pneumoperitoneum.

ICP measuring techniques are crucial for monitoring patients with possible brain injuries or disorders. Intraventricular catheters, intraparenchymal, and epidural sensors are examples of invasive procedures that offer a more precise ICP assessment. These methods require direct insertion into the brain tissue or outer layer of the brain.[11] On the other hand, non-invasive techniques like transcranial ultrasonography, tympanic membrane displacement study, and near-infrared spectroscopy carry less risk and require less expertise. [12] ONSD is one such non-invasive yet reliable marker deciphering ICP.

ONSD measurement using ultrasonography is a non-invasive, easy, reproducible, easy-to-learn, bedside procedure. Though the sensitivity of detecting raised ICP by this method is significantly high, the diameter can be influenced by various factors like age, sex, and pre-existing health conditions. In a meta-analysis of six investigations involving 231 individuals, the ultrasonographic assessment of ONSD demonstrated a sensitivity of 0.90 and a specificity of 0.85 when used to quantify ICP.[13]

Pneumoperitoneum raises arterial carbon dioxide pressure (PaCO2) during laparoscopies. For every 1 mmHg increase in arterial blood carbon dioxide pressure, cerebral blood flow rises by 1.8 mL/100 g/min, raising intracranial pressure.[14] Pneumoperitoneum can directly raise ICP by a physical action, regardless of PaCO2, according to Halverson et al.[7]

Volatile anaesthetics produce a vasodilator effect by acting on vascular smooth muscle, and this effect is more evident when the MAC is greater than 1. This cerebral vasodilation increases the cerebral blood flow, thus increasing the ICP. The use of isoflurane for maintenance of anaesthesia in this study might contribute to the increase in ONSD along with pneumoperitoneum. However, this effect was standardised by maintaining similar MAC in all the patients in this study. [14]

A standard ONSD value has not been mentioned in literature, and different authors consider different normal ranges for ONSD. As per a study by Amini et al.[15], 5 mm was accepted as the value denoting an ICP above 20 mm Hg. The cut-off value for an ICP above 20 mmHg was determined to be 5.2 mm in a 2014 Italian study that analysed 53 patients with cerebral haemorrhage and 53 patients in the control group.[16] 5.5 mm was recognized as the value indicating an ICP in a different investigation with 134 Korean patients.[17] This signifies the necessity for more studies to determine the ONSD that reflects a raised ICP. However, this uncertainty does not affect the current study as this study evaluates the changes in ONSD at different time points of surgery rather than using a cut-off ONSD value.

The major limitation of this study is that it has been carried out in only ASA I/II patients without any pre-existing causes of raised ICP, and it's unclear whether this correlation can also be applied in patients with critical illnesses. The ONSD values may vary even though they were taken by the same individual as in other imaging investigations, which is another drawback of this study. Ballantyne et al.[18] reported that ultrasonographic measurement of ONSD has an applicator variation of 0.2 - 0.3 mm. This variance has been acknowledged as a normal byproduct of the ultrasonography apparatus. A third limitation would be the small sample size.

Conclusion

This study determines the role of monitoring ONSD and ETCO2 during pneumoperitoneum in patients undergoing laparoscopic procedures to determine the raise in ICP. This might be a helpful tool in reducing perioperative complications and enhancing recovery. Approximately

50% of the patients showed ONSD values greater than the upper limit, but these patients did not show any neurological complications. This indicates that raised ICP during CO2 pneumoperitoneum is not likely to adversely affect patients undergoing laparoscopic surgeries. Yet, the clinical implications of this increase in ICP during laparoscopy need further research with larger sizes and involving high-risk populations.

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