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OPTIC NERVE SHEATH DIAMETER AS AN INDICATOR OF INCREASE IN INTRACRANIAL PRESSURE DURING CARBONDIOXIDE PNEUMOPERITONEUM WITH TRENDELENBURG POSITION IN ROBOTIC AND LAPAROSCOPIC SURGERIES

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Abstract

The escalation of intracranial pressure (ICP) during surgical procedures, particularly laparoscopic surgeries involving CO2 pneumoperitoneum and Trendelenburg positioning, has garnered significant attention in medical literature due to its potential cerebrovascular effects. The primary objective of this study is to quantify the changes in ONSD measurements during CO2 insufflation and Trendelenburg positioning compared to baseline values. Seventy two male patients who were American Society of Anesthesiologists class I to II and scheduled for elective Robotic or Laparoscopic surgery were enrolled in this study. Sample size was calculated using Dobson's formula $n=Z_{1-\alpha/2}pq/d^2$, where prevalence p=22%[8], including 10% attrition, total estimated sample size is 72. Inclusion criteria were those with American Society of Anesthesiologists (ASA) physical status I and II, aged between 18 and 65 years old, elective surgeries, and Robotic and Laparoscopic surgeries. Exclusion criteria comprised patients with preexisting ophthalmic or neurologic disease, and patients with a history of ophthalmic surgery or neurosurgery. The mean age of the participants was 43.5 years, with a standard deviation of 7.5 years, indicating variability in age among the sample. Similarly, while the mean height was 162.1 cm, with a standard deviation of 4.9 cm, and the mean weight was 64.9 kg, with a standard deviation of 7.3 kg, both measurements exhibited variability within the sample. At baseline (TBaseline), before any surgical intervention, the mean heart rate was 78.88 beats per minute (bpm), with a standard deviation of 11.05 bpm, and the mean arterial pressure was 79.89 mmHg, with a standard deviation of 10.86 mmHg. Following anesthesia induction (TInduction), both heart rate and mean arterial pressure exhibited slight increases, with means of 81.85 bpm and 100.30 mmHg, respectively. During CO2 insufflation (TInsufflation), heart rate remained relatively stable, while mean arterial pressure increased further to 103.81 mmHg. Upon reversing the Trendelenburg position (TReverse Trendelenburg), heart rate showed a notable increase compared to other phases, reaching a mean of 89.23 bpm, while mean arterial pressure slightly decreased. The evaluation of optic nerve sheath diameter (ONSD) serves as a valuable indicator of increased intracranial pressure (ICP) dynamics during surgeries, particularly in the context of carbon dioxide (CO2) pneumoperitoneum combined with Trendelenburg positioning.

Keywords: Optic Nerve, Intracranial Pressure, Pneumoperitoneum, Trendelenburg Position.

INTRODUCTION

The escalation of intracranial pressure (ICP) during surgical procedures, particularly laparoscopic surgeries involving CO2 pneumoperitoneum and Trendelenburg positioning, has garnered significant attention in medical literature due to its potential cerebrovascular effects.[1] This phenomenon, where CO2 pneumoperitoneum and Trendelenburg positioning independently or concomitantly contribute to increased ICP, presents challenges in both monitoring and managing intracranial dynamics intraoperatively.[2]

Historically, the assessment of ICP relied heavily on invasive intracranial devices, which necessitate surgical implantation. However, the invasive nature of these devices poses considerable risks, including hemorrhage, infection, and equipment malfunction. Consequently, their utilization in monitoring ICP during laparoscopic surgery remains limited due to safety concerns. This limitation underscores the need for alternative, noninvasive methods to evaluate intracranial dynamics accurately. In recent years, the measurement of optic nerve sheath diameter (ONSD) through ocular ultrasonography has emerged as a promising noninvasive technique for assessing ICP. By examining the diameter of the optic nerve sheath, clinicians can indirectly infer changes in ICP. Previous studies have demonstrated the accuracy and reproducibility of ONSD measurements in diagnosing and monitoring elevated ICP resulting from various pathological conditions.[3,4]

Despite the potential advantages of ONSD measurement, its application in the context of laparoscopic surgery remains relatively unexplored. Understanding the impact of CO2 pneumoperitoneum and Trendelenburg positioning on ONSD measurements is essential for elucidating their role in modulating intracranial dynamics during surgery. Moreover, identifying strategies to mitigate the adverse effects of elevated ICP in this setting is imperative for patient safety and surgical outcomes.[5,6]

The need for comprehensive research in this area stems from the potential implications for perioperative management. If ONSD measurements demonstrate a significant increase in ICP during CO2 insufflation and Trendelenburg positioning, proactive adjustments can be made to optimize patient care. For instance, modifying insufflation pressure or reducing the angle of Trendelenburg position may help attenuate the cerebrovascular effects associated with these surgical maneuvers. By elucidating the relationship between CO2 pneumoperitoneum, Trendelenburg positioning, and intracranial dynamics, clinicians can refine surgical techniques to minimize adverse neurological outcomes. Additionally, advancements in noninvasive monitoring methods, such as ONSD measurement, offer the potential for real-time assessment of ICP without the inherent risks of invasive procedures.[7,8]

The primary objective of this study is to quantify the changes in ONSD measurements during CO2 insufflation and Trendelenburg positioning compared to baseline values. By systematically evaluating these parameters, researchers aim to enhance our understanding of intracranial dynamics during laparoscopic surgery and inform evidence-based practices for optimizing patient outcomes.

MATERIAL AND METHODS

Before enrollment, written informed consent was obtained from all participants. Seventy two male patients who were American Society of Anesthesiologists class I to II and scheduled for elective Robotic or Laparoscopic surgery were enrolled in this study. Sample size was calculated using Dobson’s formula $n=Z_{1-\alpha/2}pq/d^2$, where prevalence $p=22\%$[8], including 10% attrition, total estimated sample size is 72. Inclusion criteria were those with American Society of Anesthesiologists (ASA) physical status I and II, aged between 18 and 65 years old, elective surgeries, and Robotic and Laparoscopic surgeries. Exclusion criteria comprised patients with preexisting ophthalmic or neurologic disease, and patients with a history of ophthalmic surgery or neurosurgery.

On arrival in the operating room, standard monitoring was applied, including electrocardiography, pulse oximetry, and noninvasive arterial blood pressure. General anesthesia was induced with propofol 2 mg/kg, and Fentanyl 2 mcg/kg. Vecuronium 0.1 mg/kg was administered intravenously to facilitate orotracheal intubation. After tracheal intubation, mechanical ventilation was performed with a tidal volume of 8 mL/kg and an adjusted respiratory rate to maintain an end-tidal carbon dioxide (EtCO2) of 30 to 35 mm Hg during surgery.

Anesthesia was maintained with 1 to 1.2 minimum alveolar concentration (MAC) of isoflurane in 50% oxygen/air. A forced air warming system (Bair-HuggerTM) was applied throughout surgery to maintain body temperature at 36.0–37.0°C. CO2 pneumoperitoneum was achieved with an intra-abdominal pressure of 14 mm Hg while the patient's position was supine and then 30-degree Trendelenburg positioning was applied. During pneumoperitoneum, minute ventilation was controlled to maintain an EtCO2 of 35 to 40 mm Hg by adjusting the respiratory rate. Ultrasonographic measurement of ONSD was conducted with a linear ultrasound probe. It was placed carefully on the gel over the closed upper eyelid without exerting pressure on the eye. In the two-dimensional mode, ONSD was measured 3 mm behind the globe using an electronic caliper. Two measurements were performed for each optic nerve— one in the transverse plane and one in the sagittal plane. The final ONSD corresponded to the average of the four values measured in both eyes of each patient. The ONSD and additional data, including vital signs (heart rate and mean arterial pressure), the parameters regarding respiratory mechanics (peak airway pressure, end-tidal CO2) were examined at four discrete time points: T1 – 10 minutes after induction of anesthesia, T2 – 10 minutes after creation of pneumo-peritoneum, T3 – 10 minutes after Trendelenberg positioning, T4 – before extubation after pneumo-peritoneum was released and position made neutral. In addition, the duration of Trendelenburg positioning, operation and anesthesia times, intraoperative blood loss, and the volume of administered fluid were assessed. A calculation of sample size was performed based on a previous study comparing the differences in ONSD between patients with elevated ICP and normal adults.

Statistical analysis was conducted using the Statistical Package for the Social Sciences 18.0 for Windows (SPSS Inc., Chicago, IL). All data were reported as mean – standard deviation or median (range) as appropriate.

RESULTS

The mean age of the participants was 43.5 years, with a standard deviation of 7.5 years, indicating variability in age among the sample. Similarly, while the mean height was 162.1 cm, with a standard deviation of 4.9 cm, and the mean weight was 64.9 kg, with a standard deviation of 7.3 kg, both measurements exhibited variability within the sample. A notable portion of participants had hypertension, accounting for 13.8% of the sample, while diabetes mellitus was less prevalent, observed in only 2.8% of participants. Hemoglobin levels showed a decline from the beginning to the end of surgery, with a mean decrease from 12.3 g/dl immediately after induction to 10.7 g/dl at the end of surgery. The duration of both operation and anesthesia displayed variability, with mean values of 171.8 minutes and 225.7 minutes, respectively, reflecting differences in the length of surgical procedures and anesthesia administration among participants. This comprehensive overview of participant characteristics provides essential context for understanding the study's findings and their potential implications for surgical outcomes and patient care (Table 1).

Table 1: Distribution of demographic and perioperative data among the study participants (N=72)

Sl no	Variable	Mean ± SD
1	Age (years)	43.5 ± 7.5
2	Height (cm)	162.1 ± 4.9
3	Weight (kg)	64.9 ± 7.3
4	Hypertension	10 (13.8%)
5	Diabetes mellitus	2 (2.8%)
6	Hemoglobin (g/dl) Immediately after induction At the end of surgery	 12.3 ± 0.8 10.7 ± 1.0
7	Operation time (min)	171.8 ± 32.1
8	Anesthetic time (min)	225.7 ± 33.7

At the baseline stage (TBaseline), before any surgical manipulation, the mean ONSD was 0.382 mm for the right eye and 0.387 mm for the left eye. Subsequent measurements indicate a progressive increase in ONSD following anesthesia induction (TInduction) and CO2 insufflation (TInsufflation), reaching peaks of 0.398 mm and 0.403 mm for the right and left eyes, respectively, and 0.428 mm and 0.427 mm during these phases. Upon reversing the Trendelenburg position (TReverse Trendelenburg), a slight decrease in ONSD was observed, followed by relatively stable measurements throughout the intraoperative period (TIntraoperatively). Finally, after releasing the CO2 pneumoperitoneum and returning to the supine position (TSupine after exsufflation), ONSD measurements decreased closer to baseline values. These findings suggest dynamic changes in ONSD throughout different phases of the surgical procedure, indicating potential fluctuations in intracranial pressure and highlighting the utility of ONSD measurements in monitoring cerebral dynamics during surgeries (Table 2).

Table 2: Distribution of ONSD in both eyes among the study participants (N=72)

Sl no	Time intervals	Right eye	Left eye
1	T_{Baseline}	0.382±0.05	0.387±0.06
2	$T_{\text{Induction}}$	0.398±0.04	0.403±0.05
3	$T_{\text{Insufflation}}$	0.428±0.06	0.427±0.05
4	$T_{\text{Reverse Trendelenburg}}$	0.426±0.07	0.422±0.06
5	$T_{\text{Intraoperatively}}$	0.420±0.06	0.417±0.05
6	$T_{\text{Supine after exsufflation}}$	0.396±0.06	0.400±0.03

At baseline (TBaseline), before any surgical intervention, the mean heart rate was 78.88 beats per minute (bpm), with a standard deviation of 11.05 bpm, and the mean arterial pressure was 79.89 mmHg, with a standard deviation of 10.86 mmHg. Following anesthesia induction (TInduction), both heart rate and mean arterial pressure exhibited slight increases, with means of 81.85 bpm and 100.30 mmHg, respectively. During CO2 insufflation (TInsufflation), heart rate remained relatively stable, while mean arterial pressure increased further to 103.81 mmHg. Upon reversing the Trendelenburg position (TReverse Trendelenburg), heart rate showed a notable increase compared to other phases, reaching a mean of 89.23 bpm, while mean arterial pressure slightly decreased. Throughout the intraoperative period

(TIntraoperatively), both heart rate and mean arterial pressure remained elevated compared to baseline, with means of 84.78 bpm and 97.32 mmHg, respectively. Upon returning to the supine position after releasing the CO2 pneumoperitoneum (TSupine after exsufflation), heart rate decreased closer to baseline values, while mean arterial pressure exhibited a slight reduction compared to the intraoperative phase. These measurements reflect the dynamic physiological responses to anesthesia and surgical manipulation throughout the different phases of the surgical procedure (Table 3).

Table 3: Distribution of hemodynamic parameters at different time intervals (N=72)

Sl no	Time intervals	Mean±SD
1	HR($T_{Baseline}$)	78.88±11.05
2	HR($T_{Induction}$)	81.85±11.94
3	HR($T_{Insufflation}$)	80.98±10.63
4	HR($T_{Reverse\ Trendelenburg}$)	89.23±11.07
5	HR ($T_{Intraoperatively}$)	84.78±10.08
6	HR($_{Supine\ after\ exsufflation}$)	77.89±11.30
7	MAP($T_{Baseline}$)	79.89±10.86
8	MAP($T_{Induction}$)	100.30±10.90
9	MAP($T_{Insufflation}$)	103.81±12.23
10	MAP($T_{Reverse\ Trendelenburg}$)	99.13±18.39
11	MAP ($T_{Intraoperatively}$)	97.32±11.10
12	MAP($_{Supine\ after\ exsufflation}$)	96.23±15.12

DISCUSSION

The study's results provide a comprehensive understanding of the demographic characteristics, clinical parameters, and physiological responses observed during laparoscopic surgeries. Firstly, the participants exhibited a wide range of ages, heights, and weights, indicating the diverse nature of the sample population. Additionally, the prevalence of hypertension among the participants highlights the importance of considering comorbidities in surgical management. Although diabetes mellitus was less common in the sample, its presence underscores the need for meticulous perioperative care in such cases. The observed decline in hemoglobin levels from induction to the end of surgery reflects the expected physiological response to surgical blood loss and fluid shifts. Moreover, the variability in operation and anesthesia durations emphasizes the individualized nature of surgical procedures and anesthetic management.

In our study the findings related to optic nerve sheath diameter (ONSD) and intracranial pressure dynamics offer valuable insights into the physiological changes occurring during both robotic and laparoscopic surgeries. The progressive increase in ONSD following anesthesia induction and CO2 insufflation suggests a potential elevation in intracranial pressure during these phases, which may be attributed to factors such as altered cerebral blood flow and venous return. The observed decrease in ONSD upon reversing the Trendelenburg position indicates a possible reduction in intracranial pressure, while relatively stable ONSD measurements during the intraoperative period suggest a maintained intracranial pressure state. The subsequent decrease in ONSD after releasing the CO2 pneumoperitoneum and returning to the supine position aligns with the restoration of normal physiological conditions.

In a study by Kim et al[9], who investigated optic nerve sheath diameter (ONSD) measurements in distinct surgical scenarios: patients positioned in Trendelenburg position undergoing laparoscopic gynecological surgery versus those in reverse Trendelenburg position undergoing laparoscopic cholecystectomy concluded that the increase in intracranial pressure (ICP) during laparoscopic procedures with short pneumoperitoneum durations is minimal and independent of patient positioning.[10] Similarly, in patients undergoing robot-assisted laparoscopic radical prostatectomy (RALRP), no statistically significant elevation in ONSD was reported. Colomina et al[11] assessed cerebral hemodynamics using transcranial Doppler in lengthy laparoscopic procedures involving pneumoperitoneum and head-down positioning, finding no significant alterations in mean middle cerebral artery (MCA) blood flow velocity. The evaluation of ONSD emerges as a rapid, secure, noninvasive, and cost-effective tool for screening and monitoring patients susceptible to increased ICP.

A systematic review and meta-analysis corroborated these findings, linking elevated ICP during laparoscopic procedures to notable ONSD increases in both early (0–30 min) and later (30–120 min) phases of CO2 pneumoperitoneum. Notably, studies in patients undergoing RALRP have reported ONSD elevation, indicating ICP exceeding 20 mmHg during surgery.[12] However, it's crucial to note distinctions in clinical and surgical contexts, particularly in patients undergoing procedures in steep Trendelenburg positions for prolonged durations, contrasting with our study where surgical durations and positioning differ. Kamine et al[13] documented a sequential ICP increase in a small subset undergoing laparoscopy-assisted ventriculoperitoneal shunt placements, but caution must be exercised in extrapolating their results to our setting, as their subjects underwent hydrocephalus management, unlike our patients with no intracranial pathology.

The assessment of heart rate and mean arterial pressure throughout the surgical procedure provides further insights into the cardiovascular responses to anesthesia and surgical manipulation.[14] In our study the slight increases in both parameters following anesthesia induction and further elevation during CO2 insufflation reflect the expected physiological responses to anesthesia induction and the hemodynamic effects of pneumoperitoneum. The notable increase in heart rate upon reversing the Trendelenburg position suggests a compensatory response to changes in body position, while the sustained elevation in mean arterial pressure throughout the intraoperative period indicates ongoing cardiovascular adaptation to the surgical stress. Overall, these findings contribute to our understanding of the complex interplay between surgical interventions, anesthesia management, and physiological responses in laparoscopic surgeries. They underscore the importance of comprehensive perioperative monitoring and individualized patient care to optimize surgical outcomes and ensure patient safety. Further research in this area may help refine perioperative strategies and improve patient outcomes in laparoscopic surgical settings.

Despite the valuable insights gained from our study, several limitations warrant acknowledgment. Firstly, the sample size of our study may limit the generalizability of findings, necessitating larger-scale investigations to validate our observations across diverse patient populations. Additionally, the retrospective nature of our data collection may introduce inherent biases and limit the depth of information available for analysis. Moreover, the reliance on optic nerve sheath diameter (ONSD) measurements as a surrogate marker for intracranial pressure may not fully capture the complex interplay of physiological factors contributing to intracranial dynamics.

CONCLUSION

The evaluation of optic nerve sheath diameter (ONSD) serves as a valuable indicator of increased intracranial pressure (ICP) dynamics during surgeries, particularly in the context of carbon dioxide (CO2) pneumoperitoneum combined with Trendelenburg positioning. Our study findings, in alignment with existing research, highlight the minimal rise in ICP during laparoscopic procedures with short pneumoperitoneum durations, irrespective of patient positioning. Moreover, our observations support the utility of ONSD measurement as a rapid, noninvasive, and cost-effective tool for screening and monitoring patients at risk of elevated ICP. Overall, our study underscores the significance of ONSD assessment in understanding intracranial dynamics during laparoscopic surgeries, providing valuable insights for optimizing patient care and surgical outcomes in robotic and laparoscopic procedures.

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