Intraocular Pressure Changes during Laparoscopic Surgery in Trendelenburg Position in Patients Anesthetized with Propofol-based Total Intravenous Anesthesia Compared to Sevoflurane Anesthesia: A Comparative Study

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Abstract

Background: Intraocular pressure (IOP) is increased during laparoscopic surgery with Trendelenburg position and may contribute to deleterious effects on optic nerve in susceptible patients. Aims: The primary objective of this study is to compare the effects of propofol-based total intravenous anesthesia (TIVA) with those of sevoflurane anesthesia on IOP in patients undergoing lower abdominal laparoscopic surgery in Trendelenburg position. Secondary objectives are to compare hemodynamic changes, mean arterial pressure (MAP), end-tidal CO₂, and peak inspiratory pressure changes. Materials and Methods: Sixty patients with physical status American Society of Anesthesiologists classes I and II were randomly allocated in two groups: Group A (propofol) and Group B (sevoflurane). IOP along with other parameters was measured at seven points including baseline (T0), 5 min after induction (T1), 5 min after CO₂ pneumoperitoneum in supine position (T2), 30 min after CO₂ pneumoperitoneum with Trendelenburg position (T3), 5 min after returning to supine position (T4), 5 min after CO₂ desufflation (T5), and 5 min after extubation (T6). Results: The change in IOP was different between the two groups. Maximum rise in IOP was seen at T3, and mean ± standard deviation IOP was 15.5 ± 0.9 mmHg and 19.8 ± 1.2 mmHg in Group A and Group B, respectively (P < 0.01). In Group A (propofol), IOP remained almost equal to the baseline value at T3 and the IOP difference was 0.3 ± 0.9 mmHg less than baseline (statistically insignificant, P > 0.05), while in Group B (sevoflurane), IOP increased significantly at T3 and the difference was 4.0 ± 1.2 mmHg (P < 0.001). The IOP was significantly greater (P < 0.01) from T2 to T6 in sevoflurane group than propofol group. Conclusion: Propofol-based TIVA is more effective than inhalational anesthesia with sevoflurane in attenuating the increase in IOP during laparoscopic surgery requiring CO₂ pneumoperitoneum with Trendelenburg position.

Keywords: Intraocular pressure, laparoscopic surgery, propofol, sevoflurane, Trendelenburg position

INTRODUCTION

Laparoscopic surgery is associated with less postoperative pain, less scarring, less trauma, and shorter hospital stay as compared to open surgical procedures. Despite these advantages, laparoscopic surgery is associated with certain adverse physiological changes. The existing literature suggests that during laparoscopic surgery, the rise in intra-abdominal pressure and associated physiological changes result in a typical state of increased intraocular pressure (IOP). This increase in IOP is considerably worsened when combined with a Trendelenburg (head-down) position. It is a known fact that in head-down position, venous pressure increases within the eye which possibly leads to increase in IOP. Hypoventilation and hypercapnea increase IOP by causing choroidal congestion. Laryngoscopy, intubation, and pain are other factors associated with increase in IOP. The ocular perfusion pressure (OPP) is estimated as the difference between mean arterial pressure (MAP) and IOP. In this sense,
elevated IOP may serve as a surrogate marker of ocular venous congestion and decreased perfusion of the optic nerve. Rise in IOP and decreased OPP sometimes may contribute to ischemic optic neuropathy, leading to disastrous event of postoperative vision loss (POVL). The incidence of POVL is very rare (0.02%–0.1%) but devastating complication that has been recently reported after robotic urological surgery. Therefore, maintenance of IOP within normal range or attenuating an increase in IOP during laparoscopic surgery in Trendelenburg position remains one of the most important anesthetic challenges.

Previous studies have reported a decrease in IOP with intravenous (IV) hypnotic agents, inhalation anesthetics, and opioids. However, there is a controversy regarding the superiority of propofol over inhalational anesthetics in suppressing the increase in IOP. In some of the studies, propofol has been found to be more effective than sevoflurane and isoflurane, while few others did not find any difference. With this background, we evaluated and compared the changes in IOP in patients undergoing lower abdominal laparoscopic surgery in Trendelenburg position under general anesthesia with either propofol-based total IV anesthesia (TIVA) or inhalational anesthesia with sevoflurane.

**Materials and Methods**

The study was conducted in the Department of Anaesthesiology, SMS Medical College and Attached Group of Hospitals, Jaipur, with due permission from the committee of the Research Review Board from June 2015 to November 2015. It was hospital-based, double-blind, interventional, and randomized comparative study. Sixty patients with physical status American Society of Anesthesiologists (ASA) classes I and II of either sex aged between 18 and 50 years with body weight 35–70 kg scheduled for lower abdominal laparoscopic surgery with 25°–30° Trendelenburg position under general anesthesia were included in the study. Exclusion criteria included patient’s refusal, history of eye disease, baseline IOP >21 mmHg, difference in IOP of >8 mmHg between two eyes, diabetic retinopathy, cataract, patients who have received medication or surgery for previously diagnosed glaucoma or taking any medication which can alter IOP, major systemic disease (morbid obesity, diabetes, hypertension), history of known allergy to anesthetic agents used in study, anticipated difficult intubation, duration of surgery >3 h.

All patients were explained about the anesthetic technique and perioperative course. Informed written consent was taken from each patient. In addition to routine pre-anesthetic checkup, examination of cornea, fundus, and IOP measurements was carried out by an ophthalmologist.

Among the patients posted for elective laparoscopic surgery, the first 60 patients fulfilling the eligibility criteria and ready to provide informed written consent were randomly divided into two groups by a computer-generated table of random numbers to receive either propofol-based TIVA (Group A; n = 30) or inhalational anesthesia with sevoflurane (Group B; n = 30).

Sample size was calculated to be 27 subjects for each of the two groups at alpha (α) error 0.05 and power 80% assuming detectable difference in mean IOP at T3 to be 3.9 and standard deviation (SD) 5.1 as found in the previous study. All the investigators except the anesthesiologist who took part in the operation were blinded to group assignment. Investigator who recorded the IOP underwent training for the measurement of IOP with Schiotz tonometer in the Ophthalmology Department.

Anesthetic technique was standardized for all patients. On arrival in the operation theater, standard monitoring devices consisting of electrocardiogram (ECG), pulse oximetry, noninvasive blood pressure (NIBP), end-tidal CO₂ (EtCO₂), and bispectral index (BIS) were applied. Proparacaine 0.5% eye drop (one drop in each eye) was instilled 1 min before measurement of baseline IOP. Baseline parameters (IOP, heart rate [HR], systolic blood pressure [SBP], diastolic blood pressure [DBP], and MAP) were recorded. Two IV lines were secured and Ringer lactate drip was started at a rate of 5 ml/kg/h. Infusion rate was tailored to each patient according to intraoperative requirement.

Each patient was premedicated with injection glycopyrrolate 0.2 mg IV + injection midazolam 1 mg IV + injection fentanyl 2 µg IV along with preoxygenation for 5 min before starting induction of anesthesia. Anesthesia was induced by propofol 1.5 mg/kg IV in both groups. After loss of consciousness, injection atracurium 0.5 mg/kg IV was administered to facilitate intubation. Intubation was done with endotracheal tube of appropriate size after direct laryngoscopy. Controlled mechanical ventilation (Spacelab Blease focus Model no. 100172) was used to maintain EtCO₂ between 35 and 45 mmHg. Anesthesia was maintained with propofol infusion 5–10 mg/kg/h in Group A and sevoflurane 1%–4% (Blease datum, Model No. 109053) in Group B. Sevoflurane concentration and infusion rate of propofol were adjusted to maintain BIS value between 40 and 60 and MAP within 20% of preinduction value throughout the surgery, and mechanical ventilation was done with the mixture of 60% N₂O and 40% O₂ using a closed flow circle system. Muscle relaxation was provided by subsequent doses of injection atracurium 0.1 mg/kg.

The abdomen was insufflated with CO₂ and intra-abdominal pressure was kept <15 mmHg. Patients were then placed in the 25°–30° Trendelenburg position. HR, systemic arterial BP including MAP, SBP, DBP, EtCO₂ peak inspiratory pressure (PIP), and IOP (using Schiotz tonometer) were recorded at the following points of time [Table 1]. HR, SBP, DBP, MAP, and IOP were noted at seven predefined points (T0–T6), and PIP and EtCO₂ noted at five predefined points (T1–T5).

IOP was measured with the Schiotz tonometer, and it was calibrated before each reading. In each patient, IOP
was measured by 5.5 scale, and the average of the two measurements was calculated for each eye; the mean of the IOPs for both eyes was calculated as the patient’s IOP. Normal IOP is defined as being <21 mmHg, while IOP ≥24 mmHg is defined as the treatment indication of glaucoma. ECG, SpO₂, NIBP, EtCO₂, and BIS were monitored continuously during the intraoperative period. MAP was maintained within ±20% of baseline value.

Reversal was done with IV injection neostigmine (0.05 mg/kg IV) + injection glycopyrrolate (0.01 mg/kg IV) after onset of spontaneous respiration. Exubation was done when adequate motor power was regained.

Statistical analysis
All the data were entered on Excel sheet and analyzed statistically using Primer software and XL-Stat. All the quantitative data were summarized in the form of mean ± SD. The difference between mean value of both the groups was analyzed using Student’s t-test, and for intragroup comparison, paired t-test was used. All the qualitative data (sex and ASA grade) were summarized in the form of number and percentage and were analyzed using Chi-square test. The levels of significance and α error were kept 95% and 5%, respectively, for all statistical analysis.

RESULTS
The data were distributed normally with respect to age, weight, sex, and ASA grade, and there was no significant difference between the two groups [Table 2]. Preoperative HR, BP, and IOP were also comparable in both the groups [Tables 3 and 4]. Variation in MAP followed a similar and comparable trend in both the groups, and intergroup comparison between Group A and Group B was statistically insignificant (P > 0.05).

The baseline IOP (T0) was similar in both groups, with mean ± SD values being 15.87 ± 0.9 mmHg in Group A (propofol) and 15.89 ± 0.8 mmHg in Group B (sevoflurane); P > 0.05 [Figure 1]. After induction of anesthesia (T1), IOP decreased significantly (P < 0.05) as compared to baseline value (T0) in both the groups; 12.39 ± 0.8 mmHg and 12.37 ± 0.9 mmHg in Group A and B, respectively. This fall is comparable in both Group A and Group B (P > 0.05). IOP increased with the establishment of pneumoperitoneum (T2) and Trendelenburg position (T3) in both the groups, but in Group A, IOP value at different time intervals was less than the baseline value (T0), while in Group B, IOP was more than the baseline except T5. During maintenance of anesthesia from T2 to T6, IOP was significantly greater (P < 0.05) in Group B (sevoflurane) as compared to Group A (propofol). In both the groups, the maximum rise in IOP was seen at T3 (30 min after CO₂ pneumoperitoneum with head-down position). In Group A at T3, the IOP value was 0.3 ± 0.9 mmHg less than baseline (T0) (statistically insignificant as P > 0.05). In the Group B (sevoflurane), the maximum rise in IOP was seen at T3 (30 min after CO₂ pneumoperitoneum with head-down position) as compared with baseline (T0); the difference was 4.0 ± 1.2 mmHg (P < 0.001). The IOP values at T3 were 15.5 ± 0.9 and 19.8 ± 1.2 in Group A and Group B, respectively.

Intraoperative EtCO₂ and PIP increased from T1 to T5 in both groups [Table 5], but the increase was similar in both the groups (statistically insignificant as P > 0.05). The mean duration of head-down position and mean duration of CO₂ pneumoperitoneum were comparable between the two groups [Table 2].

DISCUSSION
Laparoscopic surgery is associated with physiological changes that tend to increase IOP. These include increase of BP, EtCO₂, and central venous pressure (resulting from intra-thoracic pressure increase and postural changes). These physiological changes along with profound increase in IOP with CO₂ pneumoperitoneum and Trendelenburg position in a patient with ocular hypertension may aggravate intraocular hypertension in susceptible patients undergoing laparoscopic surgery.

There was clinically no significant difference between the two groups in demographic data. During the intraoperative period, MAP was maintained within 20% of the preoperative value.

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Table 1: Time points of intraocular pressure measurements

| Time point | Event |
|------------|-------|
| T0         | Before anesthesia induction (awake in supine horizontal position before premedication) |
| T1         | 5 min after anesthesia induction (before CO₂ pneumoperitoneum in supine, horizontal position in mechanically ventilated) |
| T2         | 5 min after establishing CO₂ pneumoperitoneum in horizontal position |
| T3         | 30 min after CO₂ pneumoperitoneum with Trendelenburg position |
| T4         | 5 min after returning to horizontal position with CO₂ pneumoperitoneum |
| T5         | 5 min after desufflation of CO₂ pneumoperitoneum |
| T6         | 5 min after tracheal extubation in the operating room |

Figure 1: Trend of intraocular pressure at different time intervals. Mean intraocular pressure in the propofol (Group A) and sevoflurane (Group B) group at different time points.
Within this range, changes in BP are poorly transmitted to the eye. With both techniques, control of BP and EtCO₂ was possible.

The baseline IOP was similar in both groups, with mean ± SD values being 15.87 ± 0.9 mmHg in Group A (propofol) and 15.89 ± 0.8 mmHg in Group B (sevoflurane). After induction of anesthesia and before pneumoperitoneum, IOP decreased significantly from the baseline value in both the groups. This effect on IOP during induction of anesthesia has been well documented during nonophthalmic surgery and is unrelated to changes in BP and HR. With the establishment of pneumoperitoneum and Trendelenburg position, IOP increased in both the groups. Our findings support the earlier studies which reported significant rise in IOP with pneumoperitoneum and Trendelenburg position. During maintenance of anesthesia from T2 to T6, IOP was significantly higher in sevoflurane group than in propofol group.

In the sevoflurane group, CO₂ insufflation resulted in a significant rise in IOP which reached its maximum at T3 (30 min after establishment of CO₂ pneumoperitoneum with Trendelenburg position). Our findings coincide with those of Yoo et al. and Mowafi et al. Although the rise in IOP in sevoflurane was statistically significant, it may be considered clinically insignificant because it remained within normal diurnal range (<20 mmHg). Our findings support the study of Lentschener et al. and Mowafi et al. They found laparoscopic surgery safe in young patients with no preexisting eye disease. In contrast, the mean IOP levels in Young’s study were >20 mmHg. This discrepancy between their study and our study seems to be due to the difference in the study population. While mean age in our study and Mowafi’s study was 30.53 and 30.0 years, respectively, most patients in Young’s study were older than 60 years.

In the propofol group, although IOP increased after pneumoperitoneum and Trendelenburg position as compared to postinduction levels, it remained less than the baseline IOP.

Thus, in the present study, we found that propofol-based TIVA is more effective than sevoflurane-based inhalational anesthesia in attenuating the increase in IOP during lower abdominal laparoscopic surgery performed in Trendelenburg position. Schäfer et al. reported that the decrease in IOP during cataract surgery was significantly greater with propofol-based TIVA than sevoflurane anesthesia. Moreover, Mowafi et al. and Yoo et al. found that propofol-based TIVA was superior to isoflurane and sevoflurane inhalational anesthesia, respectively, in attenuating the increase in IOP during laparoscopic surgery in Trendelenburg position. In contrast to our findings, Sator et al. reported that sevoflurane and propofol decrease IOP equally during open gynecological and urological surgeries. This discrepancy could be because of difference in the type of surgery (laparoscopic versus open surgery).

The mechanism by which propofol decreases IOP is postulated to be its ability to depress the ocular centers of the brain.
Depression of these central nervous system ocular centers could cause a decrease in IOP by relaxing extraocular muscle tone, facilitating aqueous drainage, or both.\textsuperscript{[16,17]} Another mechanism of action for the taming effect on IOP during laparoscopic surgery is attributable to the effect of propofol on arginine vasopressin (AVP), which is markedly increased during laparoscopy, especially after insufflation and Trendelenburg position.\textsuperscript{[18,19] AVP and its synthetic derivative desmopressin produce a dose-dependent increase in IOP.\textsuperscript{[20,21]} Propofol inhibits the somatodendritic AVP release from the supraoptic nucleus\textsuperscript{[22]} and may therefore prevent the increase of IOP associated with pneumoperitoneum and the Trendelenburg position. Inhaled anesthetics, however, do not affect the release of AVP.\textsuperscript{[23]} Further investigations are required to prove this mechanism.

The results of the present study have clinical significance that propofol may decrease the risk of damage to the optic nerve during laparoscopic surgery by attenuating the increase in IOP and therefore decreasing the risk of ocular hypoperfusion. Moreover, propofol is less expensive and easily available than sevoflurane. Thus, propofol-based TIVA may be a better alternative as compared to inhalational anesthesia for maintenance of anesthesia during laparoscopic surgery in Trendelenburg position.

**Limitations of the study**

Since this study was conducted in ASA I and II, young subjects with no preexisting eye disease, further studies are necessary to rule out a possible negative effect of increased intraperitoneal pressure on IOP in older patients with preexisting eye disease. The duration of the surgery was relatively less. The mean duration of pneumoperitoneum in Trendelenburg position was approximately 90 min. Longer operative times have been correlated with the ischemic optic neuropathy in spine surgeries in prone position as well as in steep Trendelenburg position.\textsuperscript{[24]}

Thus, the clinical effects of propofol-based TIVA to reduce IOP in surgeries of longer duration are not clear. Central venous pressure was not measured in this study. In our opinion, this is not a weak point of this study since CVP changes associated with intraperitoneal pressure and posture changes have already been accurately investigated in several studies.\textsuperscript{[24]}

**Conclusion**

Propofol-based TIVA is more effective than inhalational anesthesia with sevoflurane in attenuating the increase in IOP during lower abdominal laparoscopic surgery requiring CO\textsubscript{2} pneumoperitoneum with Trendelenburg position. Further studies are required to prove the safety of laparoscopy in Trendelenburg position with regard to IOP changes, especially in older patients and those with preexisting eye diseases.

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**Conflicts of interest**

There are no conflicts of interest.

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