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Effects of Inhalation Anaesthesia and Total Intravenous Anaesthesia on Intraocular Pressure in Robotic Prostate Surgery

Robotik Prostat Cerrahisinde İnhalasyon Anestezisi ve Total İntravenöz Anestezinin Göz İçi Basıncı Üzerindeki Etkileri

Aysun ERŞEN YÜNGÜL[1]
[1]Department of Anesthesiology, Ankara Bilken City Hospital, Ankara, Türkiye

Bilge ASLAN[2]
[2]Health Sciences University, Ankara Bilkent City Hospital, Department of Anesthesiology and Reanimation, Ankara, Türkiye

Ayça Tuba DUMANLI ÖZCAN[2]
[2]Health Sciences University, Ankara Bilkent City Hospital, Department of Anesthesiology and Reanimation, Ankara, Türkiye

Abdulkadir BUT[3]
[3]Yıldırım Beyazıt University, Clinic of Head of Anesthesia and Reanimation, Ankara, Türkiye

ABSTRACT

Objective: This study aimed to compare the effects of inhalation anesthesia and total intravenous anesthesia on intraocular pressure, as well as to evaluate associated hemodynamic changes, surgical duration, blood gas parameters, and the effects of pneumoperitoneum and steep trendelenburg positioning at different time intervals in patients undergoing robotic prostatectomy. Robot-assisted laparoscopic prostatectomy (RALP) is widely used in the surgical treatment of prostate cancer. Due to patient characteristics, operative duration, and the requirement for a steep Trendelenburg position, RALP is associated with specific physiological changes. One of the most important concerns is the increase in intraocular pressure (IOP), which may lead to ocular complications. This study aimed to compare the effects of inhalation anesthesia and total intravenous anesthesia (TIVA) on intraoperative IOP changes during robotic prostate surgery.

Methods: This prospective randomized study included 60 patients scheduled for elective robotic prostatectomy following ethics committee approval. Patients were randomly allocated into two groups: Group 1 received sevoflurane–remifentanil anesthesia, and Group 2 received propofol–remifentanil anesthesia. Intraocular pressure, hemodynamic variables, blood gas parameters, respiratory mechanics, heart rate (HR), systolic, diastolic and mean blood pressures (SBP, DBP, MBP), bispectral index (BIS), peripheral oxygen saturation (SpO_2), and end-tidal carbon dioxide ($ETCO_2$) were recorded at predefined time points from anesthesia induction to the postoperative period.

Results: Demographic characteristics, comorbidities, anesthesia duration, Trendelenburg duration, pneumoperitoneum duration, and surgical time were comparable between the groups (P>.05). No statistically significant difference was observed between the groups with respect to right or left intraocular pressure (IOP) measurements throughout the study period (P>.05). End-tidal carbon dioxide ($ETCO_2$) levels and mean airway pressure were significantly higher in the sevoflurane group (P<.05). In both eyes, IOP showed a positive correlation with heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean blood pressure (MBP) at T1, as well as with $ETCO_2$ at T8 (P<.05). No significant correlation was found between IOP and peripheral oxygen saturation (SpO_2) or arterial oxygen tension (PaO_2) (P>.05).

Conclusion: Although many perioperative factors affect intraocular pressure during robotic prostatectomy, no significant difference was observed between total intravenous anesthesia and inhalation anesthesia in terms of intraocular pressure changes.

Keywords: Robot-assisted laparoscopic prostatectomy, intraocular pressure, anesthetic technique, inhalation anesthesia, total intravenous anesthesia

This study has not been presented elsewhere and is adapted from the specialization thesis of Medical Doctor Aysun Erşen Yüngül.

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Sorumlu Yazar/Corresponding author: Bilge ASLAN
E-mail: drbilgeaslan@hotmail.com

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ÖZ

Amaç: Bu çalışmanın amacı, robot yardımlı laparoskopik prostatektomi uygulanan hastalarda inhalasyon anestezisi ile total intravenöz anestezinin intraoküler basınç üzerindeki etkilerini karşılaştırmak; ayrıca buna eşlik eden hemodinamik değişiklikler, cerrahi süre, kan gazı parametreleri ile pnömoperitoneum ve dik trendelenburg pozisyonunun farklı zaman aralıklarındaki etkilerini değerlendirmektir.

Yöntemler: Bu prospektif ve randomize çalışmaya, etik kurul onayı alındıktan sonra elektif robot yardımlı prostatektomi planlanan toplam 60 hasta dahil edildi. Hastalar rastgele iki gruba ayrıldı. Grup 1'e sevofluran–remifentanil ile inhalasyon anestezisi, Grup 2'ye ise propofol–remifentanil ile total intravenöz anestezi uygulandı. İntraoküler basınç, hemodinamik değişkenler, kan gazı parametreleri, solunum mekanikleri, kalp hızı, sistolik, diyastolik ve ortalama kan basınçları, bispektral indeks, periferik oksijen satürasyonu ve end-tidal karbondioksit düzeyleri; anestezi indüksiyonundan postoperatif döneme kadar önceden belirlenmiş zaman noktalarında kaydedildi.

Bulgular: Gruplar arasında demografik özellikler, komorbiditeler, anestezi süresi, Trendelenburg süresi, pnömoperitoneum süresi ve cerrahi süre açısından istatistiksel olarak anlamlı fark saptanmadı. Çalışma süresi boyunca sağ ve sol göz intraoküler basınç ölçümleri açısından gruplar arasında anlamlı bir fark gözlenmedi. End-tidal karbondioksit düzeyleri ve ortalama havayolu basıncı sevofluran grubunda anlamlı olarak daha yüksek bulundu. Her iki gözde intraoküler basınç; erken dönemde kalp hızı, sistolik, diyastolik ve ortalama kan basınçlarıyla, geç dönemde ise end-tidal karbondioksit düzeyleriyle pozitif korelasyon olduğu gösterildi. İntraoküler basınç ile periferik oksijen satürasyonu veya arteriyel oksijen basıncı arasında anlamlı bir ilişki saptanmadı.

Sonuç: Robot yardımlı prostatektomi sırasında intraoküler basınç üzerinde birçok perioperatif faktör etkili olmakla birlikte, total intravenöz anestezi ile inhalasyon anestezisi arasında intraoküler basınç değişiklikleri açısından anlamlı bir fark bulunmamıştır.

Anahtar Kelimeler: Robot yardımlı laparoskopik prostatektomi, intraoküler basınç, inhalasyon anestezisi, total intravenöz anestezi.

INTRODUCTION

Prostate cancer is one of the most common malignant tumors in men and a significant cause of morbidity worldwide.[1] Radical prostatectomy is recommended as first-line treatment for patients with localized prostate cancer and a life expectancy exceeding ten years.[2] With advances in minimally invasive surgery, robot-assisted laparoscopic prostatectomy (RALP) has become a standard approach due to its advantages over open surgery; these advantages include reduced intraoperative blood loss, reduced postoperative pain, shorter hospital stay, and earlier recovery of urinary continence and erectile function.[3]

Positioning the patient is of critical importance in robotic urological surgery. Depending on the type of surgery, a more extreme patient positioning is required in robotic surgery than in laparoscopic or conventional surgery. The most ideal patient position for many urological procedures, including robot-assisted laparoscopic prostatectomy, is the patient's steep Trendelenburg position (25-45 degrees head down) and modified lithotomy position. In addition, the Trendelenburg patient position and pneumoperitoneum applied to clarify the image in robotic surgeries cause hemodynamic changes. The increase in intraocular pressure (IOP) due to the steep Trendelenburg position is known, and many perioperative factors affect the control of the IOP increase during RALP.[4,5]

An increase in intraocular pressure (IOP) in the upright Trendelenburg position, defined in this study as a steep Trendelenburg position of approximately 25–45° head-down, is a well-known phenomenon. Increased venous pressure in the eye leads to increased intraocular pressure, which in turn reduces optic nerve perfusion and can lead to the development of ischemic optic neuropathy, a rare but serious postoperative ocular complication.[6] Several perioperative factors, including surgical duration, pneumoperitoneum, blood pressure changes, and carbon dioxide levels, can contribute to IOP elevation during RALP. Intraocular pressure can be measured using various tonometric techniques. Non-contact tonometry is a subtype of tonometry and allows non-invasive assessment of intraocular pressure without direct corneal contact. Non-contact tonometry is a non-invasive method that measures pressure using the physical characteristics of the eye without the need to insert a cannula into the eye. In our study, intraocular pressure measurements were performed using a non-contact tonometry technique (air-blown tonometry).

In pneumoperitoneum and steep Trendelenburg position, peak airway pressure, mean arterial pressure, end tidal carbon dioxide ($ETCO_2$) and duration of surgery are shown to be important predictors of increased intraocular pressure.[7] $ETCO_2$ is an important predictor and increased

CO_2 pressure causes choroidal vasodilation and increased intraocular pressure. Intravenous fluid restriction, limiting the steep Trendelenburg position time as much as possible and using eye protection bands are recommended to prevent ocular complications.[8] Considering that patients undergoing robotic radical prostatectomy are often elderly and have comorbidities associated with ocular vascular dysregulation, intraoperative intraocular pressure changes may have greater clinical implications in this population.[9]

The aim of this study was to investigate the effects of hemodynamic changes, surgical duration, blood gas parameters and anesthesia method applied on intraocular pressure due to steep Trendelenburg position and pneumoperitoneum at different time intervals in patients undergoing robotic prostatectomy.

METHODS

This study was conducted in accordance with the CONSORT guidelines for the reporting of clinical trials. Research clinical trial registration number: ClinicalTrials.gov NCT07033442. Registered 24 June 2025. Retrospectively registered.

This randomized and prospective study received ethics committee approval from the Yıldırım Beyazıt University, Faculty of Medicine Ethics Committee (Date: July 22, 2015 Decision no:152). All patients included in the study were included in the study after they were informed about the treatment to be applied and their written consent was obtained. The effect size (0.98) used in the power analysis was based on previously published studies evaluating intraocular pressure changes during robotic prostatectomy under different anesthetic techniques.[4]

The G.Power 3.1.9.7 program was used to calculate the sample size of the study. In descriptive studies, when the number of individuals in the population is unknown, the t-tests-Means: Difference between two independent means (two groups) model was used to determine the sample size. When determining the sample size in the study, the first step was to determine the main hypothesis test. According to the g-power analysis, with a confidence level of 95% and a margin of error of α=0.05, an effect size of 0.98 and a tolerance rate of 5%, in this study, *P*: .05, the power of the test (1-β): 95%, t =2.00322407, noncentrality parameter δ: 3.7317288 were determined and in line with this information, the number of samples required for the study was concluded to be a total of Group 1 (n: 28) + Group 2 (n: 28) = 56 people for both groups. To compensate for potential dropouts, a total of 60 patients were included in the study.

The study included 60 patients scheduled for robotic prostatectomy. Patients with severe heart disease, restrictive or obstructive pulmonary disease, renal or hepatic insufficiency, a history of hypersensitivity to the agents used, psychiatric disorders, a history of neurological disease, a history of intracranial surgery, a history of alcohol, sedative, tranquilizer, or long-term analgesic use, glaucoma, or those using medications that could affect intraocular pressure, as well as those at risk of difficult intubation during direct laryngoscopy, were excluded. Patients who underwent open radical prostatectomy were also excluded from the analysis.

Patients were randomized in a 1:1 ratio to one of two groups using a sealed-envelope randomization method. Group 1 received inhalation anesthesia (sevoflurane–remifentanil), and Group 2 received total intravenous anesthesia (propofol–remifentanil). Randomization was performed by an operating room nurse not involved in data collection. The anesthetic technique was known to the anesthesiologist but concealed from the ophthalmologist performing IOP measurements.

No pre-operative medication was administered. Patients were placed supine on the operating table in the operating room, and non-invasive blood pressure, peripheral oxygen saturation (SpO_2), ECG, and bispectral index (BIS) monitoring were performed. Before general anesthesia, all patients had their heart rate (HR), mean arterial pressure (MAP), peripheral oxygen saturation (SpO_2), end-respiratory CO2 values, BIS values, and right/left intraocular pressure (IOP) recorded. These values were considered as the control values (T0) before general anesthesia.

Anesthesia induction was performed after pre-oxygenation with 100% oxygen for 3 minutes. In Group 1, induction agents included lidocaine (1–1.5 mg/kg), thiopental (4–6 mg/kg), remifentanil (1 μg/kg), and rocuronium (0.6–1.2 mg/kg). In Group 2, propofol (2–3 mg/kg) was used instead of thiopental, while the other agents were administered similarly. Anesthesia maintenance was achieved with sevoflurane and remifentanil infusion in Group 1 and propofol and remifentanil in Group 2, with BIS maintained between 40 and 60. Lidocaine was administered routinely during induction to attenuate the hemodynamic response to laryngoscopy and endotracheal intubation.

All anesthetic agents were discontinued upon skin closure. Residual neuromuscular block was reversed with 0,04 mg/kg neostigmine iv and 0,4 mg atropine iv for every 1 mg neostigmine. Patients were extubated after spontaneous breathing improved.

Before general anesthesia induction (T0), 10 minutes after general anesthesia induction (T1), 2 minutes after taking the patient in upright trendelenburg position (T2), 2 minutes after abdominal CO_2 insufflation (T3), 1 hour after CO_2 insufflation (T4), 2 hours after CO_2 insufflation (T5), 3 hours after CO_2 insufflation (T6), 2 minutes after CO_2 desufflation (T7), 2 minutes after switching to the supine position (T8), and 45 minutes after postoperative (T9) IOP, hemodynamic parameters, lung dynamics, blood gas parameters, HR, MBP, SBP, DBP, BIS, sPO_2 and $ETCO_2$ levels were evaluated (Table 1). Intra-abdominal pressures caused by CO_2 administered into the abdomen were recorded.

Intraocular pressure measurements were taken by the same ophthalmologist at nine predetermined time intervals for both eyes. Each patient served as their own control value. To ensure measurement consistency and reduce inter-observer variability, all intraocular pressure measurements were performed by the same examiner. Two measurements were taken for each eye at each time interval. If the difference between the measurements exceeded 5%, the measurement was repeated.

MAC was recorded for sevoflurane. During the operation, patients's PEEP, PEAK, mean airway pressure (Pmean), Pplateau, and compliance levels were recorded. MBP and HR were maintained by making necessary changes in the doses of anesthetic agents, provided that they did not change more than 30% compared to the baseline. In case of bradycardia (HR < 45 beats/min) during the intraoperative period, 0.5 mg atropine was administered IV. When MBP fell below 60 mmHg or decreased by more than 20% compared to the control value, rapid crystalloid infusion was performed. In cases where hypotension did not improve, sevoflurane, propofol, and remifentanil doses were reduced. In cases where hypotension continued, 0.1 mg/kg ephedrine hydrochloride was administered iv.

Statistical Analysis

In the study, IBM® SPSS® Statistics 25.0 (IBM SPSS Corp., Armonk, NY, USA) software program was used for statistical analysis of the data. Descriptive statistics in the study were shown as number (n) and percentages (%), numerical variables as mean and standard deviation or median (minimum - maximum). The compliance of continuous variables with the normal distribution assumption was evaluated with the Kolmogorov-Smirnow test, and as a result of this test in our study, it was determined that the data were suitable for normal distribution. Categorical variables were examined with Fisher's Exact Chi-Square test. In the comparisons of continuous variables depending on time for each group, t-test was used independent samples, and two-way analysis of variance was used in dependent samples to examine the changes in variable values by taking all time units in the groups together. Since only two independent groups were compared, independent samples t-tests were used for intergroup comparisons. Spearman correlation was used to compare numerical variables. In the comparison of quantitative variables between more than two groups, Bonferroni correction was applied to account for multiple comparisons across repeated time points. Bonferroni correction was applied as a Post-Hoc analysis. Bonferroni correction post-hoc test controls the error rate when making multiple comparisons and shows in detail which two groups there is a significant difference. The results obtained in our study were accepted as significant at a confidence interval of 95%, with a *P*<.05 value.

RESULTS

There was no statistically significant difference between the groups in terms of the demographic characteristics and clinical variables. Effect sizes are expressed as median difference, Cohen's d or risk ratio (RR) (Table 2).

Systolic blood pressure (SBP) was significantly higher in the TIVA group compared with the inhalation anesthesia group (*P*<.05). Compared with baseline values, SBP in the TIVA group showed a significant decrease at T0 and significant increases at T4, T5, T6, T7, and T8 (*P*<.05). Diastolic blood pressure (DBP) was also significantly higher in the TIVA group (*P*<.05), with significant intergroup differences observed at T5, T7, and T8 (Figure 1).

Heart rate and mean blood pressure changes over time did not differ significantly between groups (*P*>.05).

End-tidal carbon dioxide ($ETCO_2$) values were significantly higher in the inhalation anesthesia group compared with the TIVA group (*P*<.05). In the TIVA group, $ETCO_2$ values were significantly lower at T6, T7, and T8 compared with the inhalation group (*P*<.05) (Figure 2).

Intra-abdominal pressure increased following carbon dioxide insufflation in both groups. A significantly higher intra-abdominal pressure was observed in the TIVA group at T3 (*P*<.05). In both groups, intra-abdominal pressure values at T5 and T6 were significantly lower than those recorded at T3 (*P*<.05).

Table 1. Intraocular pressure measurement times

T0	Before general anesthesia induction, awake, in supine position
T1	10th minute after general anesthesia induction, in supine position
T2	2 minutes after taking upright trendelenburg
T3	2 minutes after abdominal CO_2 insufflation
T4	1 hour after CO_2 insufflation
T5	2 hours after CO_2 insufflation
T6	3 hours after CO_2 insufflation
T7	2 minutes after CO_2 desufflation
T8	2 minutes after switching to supine position
T9	45 minutes after post-op

There were no statistically significant differences between groups with respect to $PaCO_2$, positive end-expiratory pressure (PEEP), peak airway pressure (Ppeak), plateau pressure (Pplateau), or dynamic lung compliance throughout the study period (*P*>.05).

Table 2. Comparison of Demographic and Clinical Characteristics of Groups

	Inhalation (n=30)	TIVA (n=30)	Effect size (95% CI)	*P*
Age (years) (Mean±Std)	63.27±5.19	63.73±5.34	-0.10 (-0.61. 0.42)	0.733***
Height (cm) (Mean±Std)	173.87±6.20	172.10±5.51	0.30 (-0.21. 0.81)	0.248*
Weight (kg) (Mean±Std)	82.97±10.30	81.53±10.32	0.14 (-0.37. 0.64)	0.592*
BSA (m^2) (Mean±Std)	2.00±0.14	1.97±0.14	0.21 (-0.30. 0.72)	0.453*
BMI (kg/ m^2) (Mean±Std)	27.46±3.18	27.52±3.26	-0.02 (-0.52. 0.49)	0.942*
DM (n, %)	5 (16.7)	5 (16.7)	1.12 (0.62. 2.01)	1.000**
HT (n, %)	11 (36.7)	7 (23.3)	0.82 (0.67. 1.01)	0.260**
Coronary artery disease (n, %)	5 (16.7)	2 (6.7)	0.50 (0.13. 1.96)	0.212**
CKD (n, %)	0 (0.0)	1 (3.3)	0.75 (0.17. 3.28)	1.000**
COPD (n, %)	3 (10.0)	5 (16.7)	0.80 (0.62. 1.02)	0.353**
Duration of anesthesia (min)	209.93±50.60	227.60±58.65	-0.32 (-0.83. 0.18)	0.217*
Trendelenburg time (min)	167.33±43.63	179.03±53.57	-0.24 (-0.74. 0.27)	0.357*
Duration of CO_2 insuff. (min)	153.00±43.28	164.10±50.81	-0.35 (-0.86. 0.15)	0.366*
Duration of surgery (min)	173.97±45.19	199.77±54.26	-0.52 (-1.08. 0.01)	0.050*

Data presented as n (%) or mean ± SD; *P*<.05 considered as significant
*One way ANOVA test, **Chi square test,*** independent T test,
BSA: Body surface area, BMI: Body mass index, DM: Diabetes mellitus, HT: Hypertension, CKD: Chronic Kidney Disease, COPD: Chronic Lung Disease

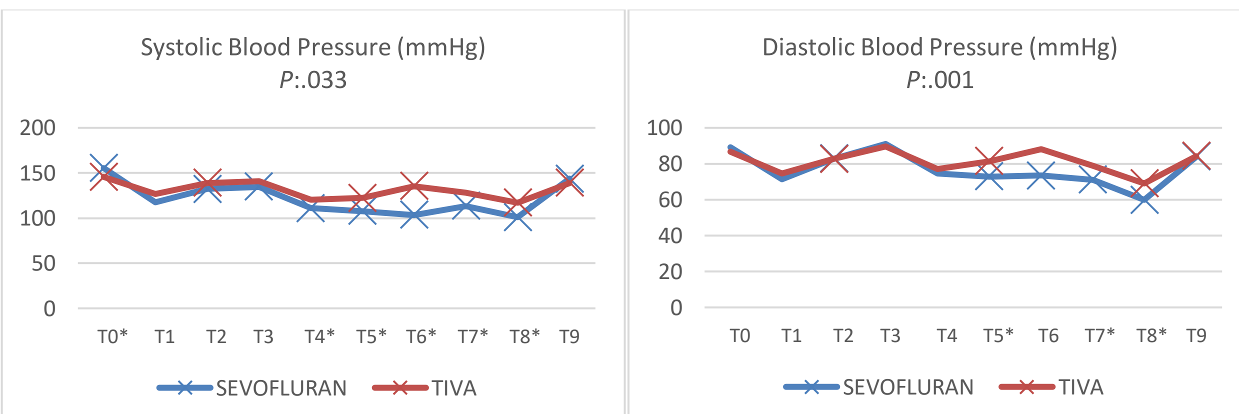

Figure 1. Changes in Systolic and Diastolic Blood Pressure Over Time
*: difference between groups *P*<.05; X: difference in change of drug compared to baseline *P*<.05

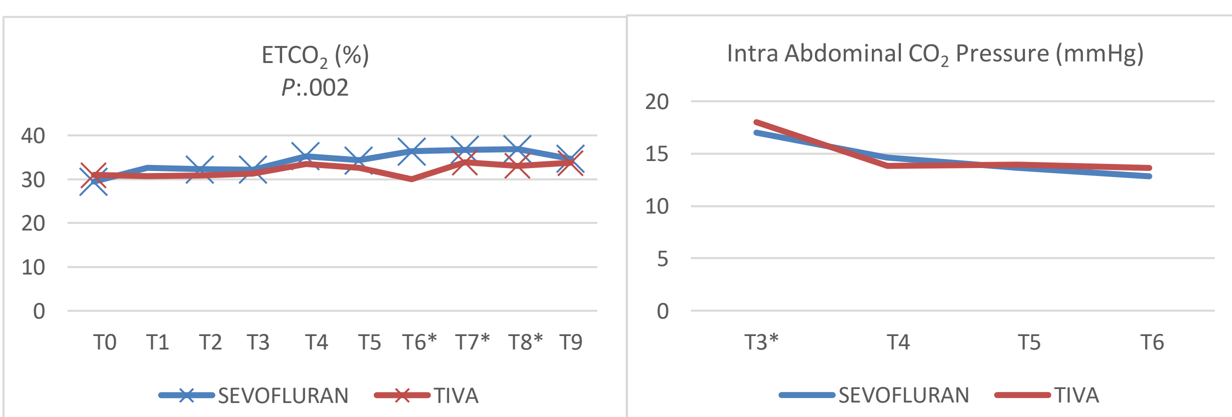

Figure 2. Changes in $ETCO_2$ and Intra-Abdominal CO_2 Pressure Over Time
*: difference between groups *P*<.05; X: difference in change of drug compared to baseline *P*<.05

Right eye intraocular pressure (IOP) did not differ significantly between the inhalation anesthesia and TIVA groups at any measurement time point ($P>.05$). In both groups, right eye IOP values were significantly lower at T1 compared with baseline and significantly higher at T3, T4, T5, T6, and T7 compared with baseline values ($P<.05$). An increase in IOP was observed at T2 and T3 compared with the preceding time points, followed by a significant decrease at T8 ($P<.05$) (Figure 3).

Similarly, left eye IOP values did not differ significantly between groups at any time point ($P>.05$). In both groups, left eye IOP was significantly lower at T1 and significantly higher at T2, T3, T4, T5, T6, and T7 compared with baseline ($P<.05$). A significant decrease in left eye IOP was observed after return to the supine position at T8 ($P<.05$) (Figure 4).

Overall, repeated-measures analysis demonstrated no significant interaction between anesthetic technique and time for either right or left eye IOP ($P>.05$).

Correlation analysis revealed a positive association between intraocular pressure (both right and left eyes) and heart rate as well as systolic, diastolic, and mean blood pressures at T1 ($P<.05$). Additionally, a positive correlation was observed between $ETCO_2$ levels and intraocular pressure at T8 ($P<.05$). No significant correlations were found between intraocular pressure and peripheral oxygen saturation, arterial oxygen tension, or airway pressure parameters ($P>.05$).

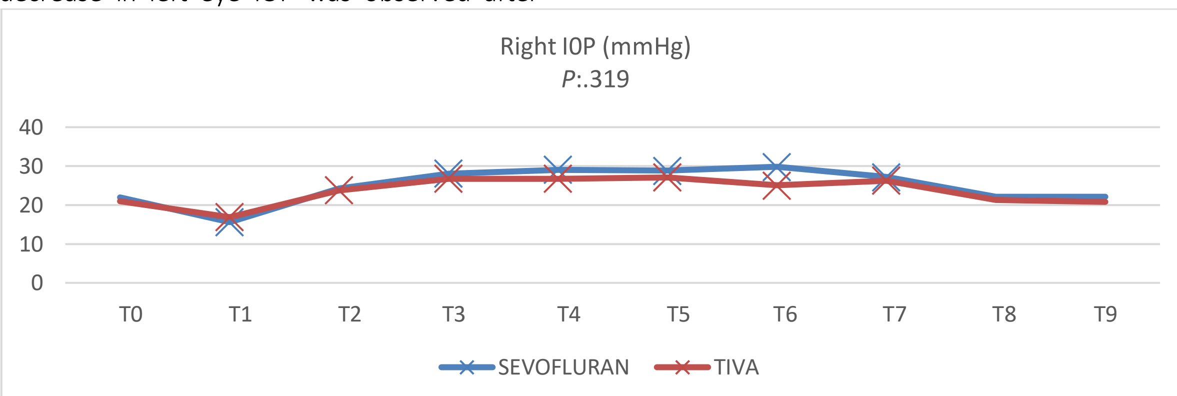

Figure 3. Change in right IOP over time
X: change from baseline within each anesthetic group, $P<.05$

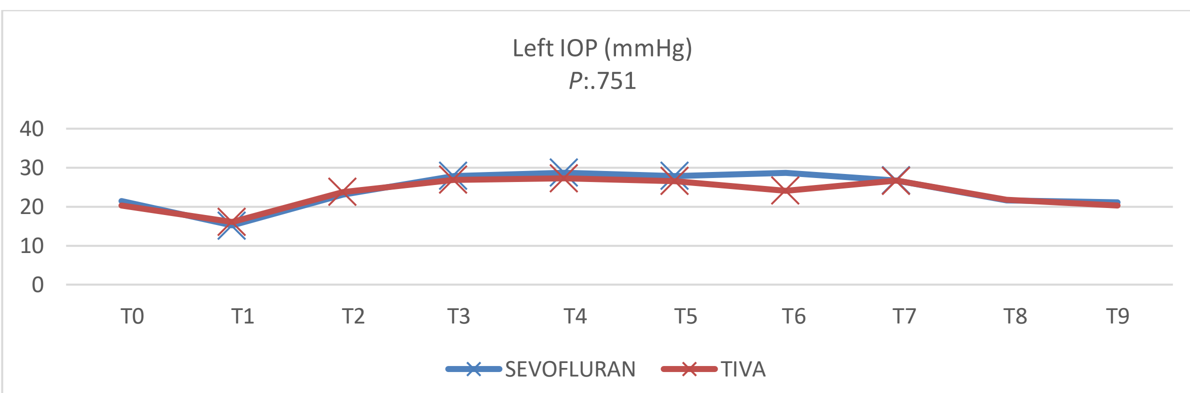

Figure 4. Change in left IOP over time
*: difference between groups $P<.05$; X: difference in change of drug compared to baseline $P<.05$)

DISCUSSION

In this study, no statistically significant difference in intraocular pressure (IOP) was observed between the total intravenous anesthesia (TIVA) and sevoflurane anesthesia groups in either eye. In both groups, IOP decreased significantly within the first 10 minutes following anesthetic induction compared with baseline values and subsequently increased during the intraoperative period. Marked elevations in IOP were particularly evident after carbon dioxide (CO_2) pneumoperitoneum and during the Trendelenburg position. The early reduction in IOP following induction is most plausibly explained by anesthetic-induced systemic hypotension and relaxation of the extraocular muscles secondary to neuromuscular blockade. These findings indicate that intraoperative IOP during robotic prostatectomy is influenced by multiple interacting factors, including anesthetic effects, patient positioning, systemic hemodynamics, and carbon dioxide levels.

Both inhalational anesthetics and TIVA have been shown to reduce IOP by decreasing extraocular muscle tone and facilitating aqueous humor outflow.[10] Kaur et al.[11] reported that propofol-based TIVA was more effective than sevoflurane-based anesthesia in attenuating IOP increases during laparoscopic procedures requiring CO_2 pneumoperitoneum in the Trendelenburg position. Additionally, propofol has been associated with smaller increases in IOP compared with volatile anesthetics.[9] The hypotensive effects of propofol are mediated through central suppression of sympathetic activity and attenuation of the baroreflex response, potentially leading to substantial reductions in diastolic and mean arterial pressures.[12] In contrast, volatile anesthetics produce dose-dependent hypotension primarily by reducing systemic vascular resistance.[13] Although arterial pressure did not differ significantly between groups in the present study, slightly higher values were observed in the sevoflurane group, which may reflect the differing hemodynamic profiles of these anesthetic agents.

Patient positioning plays a critical role in intraoperative IOP regulation.[14] Steep Trendelenburg positioning combined with CO_2 pneumoperitoneum is known to induce significant cardiovascular and neurophysiological changes during robot-assisted laparoscopic radical prostatectomy and is consistently associated with increased IOP.[11] These changes have been attributed to elevated intra-abdominal pressure, venous congestion related to aortic compression, increased end-tidal CO_2 ($ETCO_2$), and humoral factors.[4,15,16] In accordance with previous reports,[17] our study demonstrated significant IOP elevation following Trendelenburg positioning and intra-abdominal CO_2 insufflation, likely reflecting the combined effects of increased systemic blood pressure, diaphragmatic displacement, and hypercapnia.

Kondo et al.[15] reported that IOP increased by approximately 7 mmHg during Trendelenburg positioning in patients undergoing robotic prostatectomy and returned to baseline values within 30 minutes after resumption of the supine position. A similar temporal pattern was observed in our cohort. These findings support the concept that IOP is a dynamic physiological parameter influenced by posture, respiratory mechanics, and systemic circulatory changes. Furthermore, positional transitions alone have been shown to significantly affect IOP, independent of surgical intervention.[18]

Systemic blood pressure is another important determinant of IOP.[19] Although vascular autoregulation generally limits the impact of moderate blood pressure changes on IOP,[20] this mechanism may become insufficient when certain thresholds are exceeded.[21] Large population-based studies have demonstrated a significant association between systemic blood pressure and IOP variability.[21] Increased arterial pressure has been shown to augment choroidal blood flow, resulting in elevated intraocular volume and pressure.[22] In the present study, the characteristic pattern of early post-induction IOP reduction followed by intraoperative elevation and postoperative normalization is most likely related to anesthetic-induced hypotension followed by compensatory hemodynamic responses mediated by autoregulation and fluid administration.

During pneumoperitoneum and steep Trendelenburg positioning, peak airway pressure (Ppeak), mean blood pressure (MBP), $ETCO_2$ levels, and surgical duration are considered major contributors to IOP elevation. In our study, the duration of Trendelenburg positioning was comparable between groups, and IOP increased consistently during the head-down phase. These findings are consistent with previous studies reporting progressive IOP elevation during prolonged Trendelenburg positioning.[14,23] Awad et al.[24] identified $ETCO_2$ levels and surgical duration as the strongest predictors of intraoperative IOP elevation, reporting mean increases of approximately 13 mmHg during steep Trendelenburg pneumoperitoneum.

Elevations in $ETCO_2$ during laparoscopic surgery result from reduced thoracopulmonary compliance, increased airway pressures, ventilation–perfusion mismatch, and systemic absorption of insufflated CO_2.[25] Hypercapnia induces choroidal vasodilation, leading to increased intraocular blood volume and pressure. In the present study, ventilatory adjustments were implemented to maintain near-normocapnia despite increases in $ETCO_2$ during pneumoperitoneum. The similar $ETCO_2$ profiles observed between anesthetic techniques suggest that, under standardized ventilatory management, anesthetic choice may exert limited influence on CO_2 accumulation.[26]

The relative effects of TIVA and inhalational anesthesia on IOP in non-ophthalmic surgery remain controversial.[27] Variability among studies may be attributed to differences in patient demographics, surgical procedures, duration of surgery, and degree of head-down positioning.[28] While some studies suggest that propofol may attenuate IOP increases more effectively during Trendelenburg positioning,[9,30] others emphasize the dominant role of pneumoperitoneum and positioning rather than anesthetic technique alone.[29] Our findings support the latter perspective, indicating that intraoperative IOP elevation during robotic prostatectomy is primarily driven by positional and physiological factors.

Sustained intraoperative IOP elevations exceeding 21 mmHg during robotic surgery have been associated with postoperative ocular complications, including glaucoma, ischemic optic neuropathy, impaired optic nerve perfusion, and visual loss.[4] Although a definitive causal relationship between transient intraoperative IOP elevations and long-term visual outcomes has not been conclusively established, transient visual field defects have been reported in a substantial proportion of patients undergoing robot-assisted laparoscopic prostatectomy.[9,31] In the present study, IOP was assessed only during the intraoperative period, and long-term postoperative ophthalmologic follow-up was not performed.

Robot-assisted radical prostatectomy has become a widely accepted surgical approach for the treatment of localized prostate cancer, offering enhanced precision, reduced perioperative morbidity, and favorable functional outcomes compared with open and conventional laparoscopic techniques.[32,33] Surgical success remains closely linked to surgeon experience and the learning curve associated with robotic platforms.[34] Although technological advances have standardized many aspects of robot-assisted laparoscopic prostatectomy, recent literature suggests that variations in anesthetic dosing, pneumoperitoneum pressure, and positioning protocols may exert limited influence on overall surgical outcomes.[35]

Study Limitations

This study has several limitations. First, the sample size was relatively small and the study was conducted at a single center, which may limit the generalizability of the findings. Second, although intraocular pressure was monitored intraoperatively and in the early postoperative period, long-term postoperative ophthalmologic follow-up was not performed. Therefore, the clinical significance of transient intraoperative IOP elevations could not be fully assessed. Third, blinding of the anesthesiologist to the intervention was not feasible due to the nature of the anesthetic techniques. "Different induction agents were used between groups (thiopental in the inhalation anesthesia group and propofol in the TIVA group). Different induction agents were used between groups (thiopental in the inhalation anesthesia group and propofol in the TIVA group). This difference may have influenced intraocular pressure measurements and is therefore considered a potential confounding factor and a limitation of the study.

CONCLUSION

We believe that in robotic prostatectomy surgery, controlling intraocular pressure requires appropriate and meticulous anesthesia management, where patient positioning, vital signs, CO_2 levels, ventilator parameters, and both the amount and duration of pneumoperitoneum are carefully monitored — factors that may play a more critical role than the choice of anesthetic agent.

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