Effects of propofol, desflurane, and spinal anesthesia on intraocular pressure during lumbar disc herniation surgery: a randomized controlled study

E.T. YILMAZ, B.O. KELEŞ

Department of Anesthesiology and Reanimation, Faculty of Medicine, Giresun University, Giresun, Turkey

Abstract. – OBJECTIVE: This study aims to evaluate the effects of total intravenous anesthesia (propofol), volatile anesthesia (desflurane), and spinal anesthesia on intraocular pressure (IOP) during lumbar disc herniation surgery in the prone position.

PATIENTS AND METHODS: This randomized controlled trial was conducted between January 2022 and January 2023. The study included 75 patients with lumbar disc herniation between the ages of 18-75, with the American Society of Anesthesiologists (ASA) 1-2. The patients were randomly divided into 3 groups: propofol, desflurane, and spinal. IOP was measured at 5-time points throughout surgery, including baseline (T1), 10 minutes after anesthesia (T2), 10 minutes after prone positioning (T3: early prone), 30 minutes after prone positioning (T4: late prone), and 10 minutes after returning to the supine position (T5). Hemodynamic parameters were measured at these time points. Hemoglobin and hematocrit values were measured preoperatively and on the first postoperative day.

RESULTS: There were 25 patients in each group. The groups were similar in terms of all characteristics except for weight and body mass index, which were lower in the spinal group. Propofol recipients had significantly higher T3 (prone) IOP compared to desflurane recipients ($p = 0.001$). We found no significant differences between groups in terms of T1, T2, T4, and T5 IOP. Multivariable linear regression revealed that diabetes mellitus ($p = 0.016$) and high T1 IOP ($p = 0.001$) were independently associated with higher T3 IOP. In addition, we found that the desflurane ($p < 0.001$) and spinal ($p = 0.002$) groups had significantly lower T3 IOP compared to propofol recipients after adjusting for diabetes mellitus and T1 IOP.

Conclusions: Our findings suggest that volatile anesthesia (desflurane) and spinal anesthesia are linked to lower IOP in the prone position among patients undergoing spinal surgery, in comparison to those receiving total intravenous anesthesia. There is a need to test the results with more comprehensive, population-based studies in different patient groups. ClinicalTrials gov ID: NCT06070480.

Key Words:

Adult, Anesthesia, Eye, Hemodynamics, Intraocular Pressure, Prone position.

Introduction

In spine surgery, the prone position is commonly used because it creates several advantages[1], such as earlier detection of the spinal cord and better correction of posterior element disorders and imbalances[2]. However, the prone position can cause complications that may result in permanent disability. These catastrophic complications include hypoperfusion, central nervous system lesions, peripheral nerve compression, compartment syndrome, airway swelling, and ophthalmologic complications. Although most of these complications are rare, increasing knowledge about potential complications and prevention strategies can limit morbidity[3].

Ophthalmologic complications of concern include acute angle glaucoma, conjunctival swelling, corneal abrasion, increased intraocular pressure (IOP), and postoperative vision loss (POVL)[2,4]. Even minor elevations in IOP can lead to damage in pressure-sensitive retinal ganglion cells, and sustained elevations can diminish blood flow to both the retina and choroid[5]. Furthermore, increased IOP reduces ocular blood flow, causes

Corresponding Author: E.T. Yilmaz, MD; e-mail: elvanty28@hotmail.com; elvan.yilmaz@giresun.edu.tr

optic nerve edema and ischemia, and can lead to POVL[6], which is rare (0.013% to 1%) but catastrophic[7,8]. In addition, IOP elevation is likely to be a risk factor for other ophthalmologic complications[9].

Different anesthesia techniques can help maintain IOP by lowering blood pressure, relaxing extraocular muscles, reducing aqueous humor formation, and improving fluid outflow[6]. Spinal anesthesia and general anesthesia can be used interchangeably in spine surgery, and each has different advantages and disadvantages that can impact peri-operative and postoperative features. Spinal anesthesia offers advantages such as avoiding airway devices, maintaining stable hemodynamics, reducing surgical blood loss, and lowering healthcare costs[10]. It also reduces the use of drugs[11], provides preemptive pain relief[12,13], and decreases the likelihood of various postoperative complications[14]. General anesthesia assures immobility and a safe airway throughout the procedure, but it can cause hemodynamic instability, blood loss, higher analgesic needs, nausea, and vomiting.

Although the effects of spinal and general anesthesia on the peri-operative outcomes of lumbar spine surgery have been investigated in various studies, evidence pertaining to their impact on IOP and various other factors is insufficient[15]. We therefore aimed to evaluate whether IOP could be impacted by intravenous (propofol), volatile (desflurane), or spinal anesthesia in patients undergoing lumbar disc herniation surgery. Secondarily, we assessed other parameters associated with anesthesia monitoring, such as end-tidal CO_2, heart rate (HR), bispectral index, mean arterial pressure, and body temperature.

Patients and Methods

Study Planning and Enrollment

This prospective randomized controlled study was conducted between January 2022 and January 2023, after obtaining necessary permissions from the local ethics committee (KAEK-04 /2020) and written informed consent from each of the participants.

The study included 75 patients aged between 18 and 75 who were scheduled for lumbar disc surgery with ASA 1 and 2 according to the American Society of Anesthesiologists (ASA) classification. Those who did not sign the informed consent form, patients who required emergency surgery, eye surgery recipients, subjects with acute or chronic eye diseases other than refractive errors, and individuals detected to have elevated IOP in preoperative measurements were excluded from the study.

Experimental Design

The patients were randomly divided into 3 groups: spinal anesthesia group, desflurane group, and propofol group. Standard ASA monitoring (i.e., electrocardiography, noninvasive blood pressure, and oxygen saturation) was applied to all patients after they were transferred into the operating room. In all three groups, surgeries were initiated in similar ways, with all patients in a supine position.

Age, sex, height, weight, body mass index (BMI), and comorbidities (hypertension, diabetes mellitus, coronary artery disease, chronic obstructive pulmonary disease) were recorded. Crystalloid, colloid, and blood products that had been administered to patients throughout the surgical process and their amounts were recorded. Preoperative and postoperative hemoglobin and hematocrit values were measured.

Interventions and Surgery

In the spinal anesthesia group, 3 ml of 0.5% hyperbaric bupivacaine was administered with a 25 G spinal needle through the L3-4 or L4-5 intervertebral space. The desflurane group received 1.5 - 2.5 mg/kg propofol, 0.6 - 1 mg/kg rocuronium, and 2 mcg/kg fentanyl for induction. After endotracheal intubation, anesthesia was maintained with continuous infusion of remifentanil. Remifentanil infusion was administered with a target-controlled infusion (TCI) system using a TCI device (Alaris PK, Switzerland). The target site of action concentration of remifentanil was set at 3-6 ng/mL. Propofol group was given 1.5 - 2.5 mg/kg propofol, 0.6 - 1 mg/kg rocuronium, 2 mcg/kg fentanyl for induction. After endotracheal intubation, anesthesia was maintained with continuous infusion of propofol and remifental. Propofol infusion was administered with the TCI system. The target site of action concentration of propofol was set at 2.5 - 5 mcg/mL. Bispectral Index (BIS) was used to monitor the sedative and hypnotic effects of anesthetic drugs. Desflurane concentration and propofol blood concentration were adjusted during the operation so that the BIS value was between 40 - 60. Mechanical ventilation was provided with 50% oxygen and 50% air. $EtCO_2$ was kept between 30 - 40 mm Hg, and PEEP was set at 5 cm H_2O.

Temporal Measurements

IOP has measured a total of 5 times at set time points throughout the procedures. A Reichard Tonofer XL Tonometer was used in all patients after applying a local anesthetic to the eye (proparacaine hydrochloride 0.5% eye drops). Two measurements were made at each time point, and the mean was accepted as the IOP value. The first measurement (baseline) was made after the patient was put in the supine position (T1). The second measurement was made 10 minutes after anesthesia administration and before the patients were turned to the prone position (T2). The third measurement was made 10 minutes after the patients were turned to the prone position (T3: early prone). The fourth measurement was made at the 30th minute after turning to the prone position (T4: late prone). At the end of the operation, the patients were returned to the supine position and the fifth measurement was performed after 10 minutes of returning to this position (T5).

At the same time points, we also measured mean arterial pressure (MAP), heart rate (HR), bispectral index and $EtCO_2$ values and body temperatures of the patients. The patients' vital signs were recorded every 5 minutes during the surgical procedure. MAP was stabilized to keep it within 20% higher or lower relative to the pre-induction value. Neuromuscular blockade was reversed with sugammadex in patients who received general anesthesia at the end of the operation.

Statistical Analysis

Statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was used to assess normality. Continuous variables were presented as mean ± standard deviation or median (1st quartile - 3rd quartile) based on distribution normality, while categorical variables were presented as frequency (percentage).

One-way analysis of variances (ANOVA) was used for age, weight, and body mass index due to distribution normality. The Kruskal-Wallis test was used for height, intraoperative fluid, and duration of operation due to non-normality. A Chi-square test was applied for sex, comorbidities, and hypertension. Fisher-Freeman-Halton test was used for diabetes mellitus, coronary artery disease, chronic obstructive pulmonary disease, and ASA classification. Repeated measurements and between-group analysis of variables like hemoglobin, hematocrit, IOP, HR, and MAP were performed using the two-way repeated measures ANOVA. The Mann-Whitney U test was used to analyze $EtCO_2$. The Student's *t*-test was used for the between-group analysis of the bispectral index. Friedman's ANOVA by ranks and the Kruskal-Wallis test were used respectively for the within-group and between-group analyses of body temperature. All pairwise-corrected *p*-values were calculated with the Bonferroni correction. Linear regression analyses were conducted to identify independent factors significantly associated with prone position IOP. Variables were initially assessed with univariable regression analysis, and statistically significant variables were included in the multivariable model. Two-tailed *p*-values lower than 0.05 were considered statistically significant.

Results

We included 75 patients (25 in each group), and the mean age was 56.21 ± 14.82 (range 20-85) (Figure 1). No cases of paralysis, headache, persistent paresthesia, or malaise were encountered. Body weight ($p = 0.010$) and body mass index ($p = 0.003$) were significantly lower in the spinal group than in the other groups. We found no significant differences between groups in terms of age, sex, height, comorbidities, and ASA classification (Table I).

Compared to baseline, postoperative hemoglobin ($p < 0.001$ for all) and hematocrit ($p < 0.001$, $p = 0.003$, $p = 0.015$) levels were significantly lower in all groups. Between-group comparisons revealed that all groups were similar in terms of hemoglobin and hematocrit levels. Intraoperative fluid administration was lower ($p < 0.001$), and the duration of operations was shorter ($p = 0.001$) in the spinal group compared to the other groups (Table II).

T3, T4, and T5 IOP were significantly higher than T1 in the desflurane group ($p < 0.001$). T2, T3, and T4 IOP were significantly higher than T1 in the propofol group ($p < 0.001$). T3 and T4 IOP were significantly higher than T1 in the spinal group ($p < 0.001$). T3 IOP was significantly higher in the propofol group than in the desflurane group ($p = 0.001$), while there were no significant differences between the spinal group and other groups. All groups were similar when compared for IOP values at T1, T2, T4, and T5 (Table II, Figure 2).

T3 ($p < 0.001$), T4 ($p < 0.001$), and T5 ($p < 0.001$) $EtCO_2$ were significantly higher in the propofol group than in the desflurane group. We

Table I. Descriptive characteristics of groups with regard to methods of anesthesia.

Variables	Methods of anesthesia			*p*
	Desflurane (n = 25)	Propofol (n = 25)	Spinal (n = 25)	(between groups)
Age	58.72 ± 12.51	56.56 ± 15.27	53.36 ± 16.51	0.443
Sex				0.778
Female	18 (72.0%)	18 (72.0%)	16 (64.0%)	
Male	7 (28.0%)	7 (28.0%)	9 (36.0%)	
Height, cm	165 (163 - 170)	163 (162 - 168)	165 (162 - 170)	0.540
Weight, kg	82.76 ± 13.06[a]	81.40 ± 11.5[a]	73.08 ± 10.73[b]	**0.010**
Body mass index, kg/m^2	29.78 ± 4.79[a]	29.52 ± 3.67[a]	26.25 ± 3.23[b]	**0.003**
Comorbidities	19 (76.0%)	12 (48.0%)	14 (56.0%)	0.115
Hypertension	13 (52.0%)	9 (36.0%)	11 (44.0%)	0.522
Diabetes mellitus	4 (16.0%)	4 (16.0%)	5 (20.0%)	1.000
Coronary artery disease	3 (12.0%)	0 (0.0%)	0 (0.0%)	0.102
COPD	4 (16.0%)	0 (0.0%)	0 (0.0%)	0.051
ASA classification				0.182
1	6 (24.0%)	13 (52.0%)	11 (44.0%)	
2	18 (72.0%)	10 (40.0%)	13 (52.0%)	
3	1 (4.0%)	2 (8.0%)	1 (4.0%)	

Data are given as mean ± standard deviation or median (1st quartile-3rd quartile) for continuous variables according to normality of distribution and as frequency (percentage) for categorical variables. COPD: Chronic obstructive pulmonary disease. *: Significantly different from T1 (within groups analysis of repeated measurements). [a,b]Denote pairwise comparison results of between groups analysis; if two groups have the same letter, that means there is no significant difference between them

found no significant differences between desflurane and propofol groups in terms of T2 $EtCO_2$ (Table II).

In the desflurane group, HR at T3, T4, and T5 were lower than at T1 ($p < 0.001$). In the propofol group, HR at T2 was significantly higher than at T1 ($p < 0.001$). Conversely, in the spinal group, no significant differences were observed between HR at T1 and other time points. Notably, HR at T2 was significantly lower in the spinal group compared to the other groups ($p = 0.003$). T1, T3, T4, and T5 HR were similar in all groups (Table II).

All groups demonstrated lower MAP values during peri-operative measurements compared to baseline. MAP at T3 was significantly lower in the desflurane group compared to the other

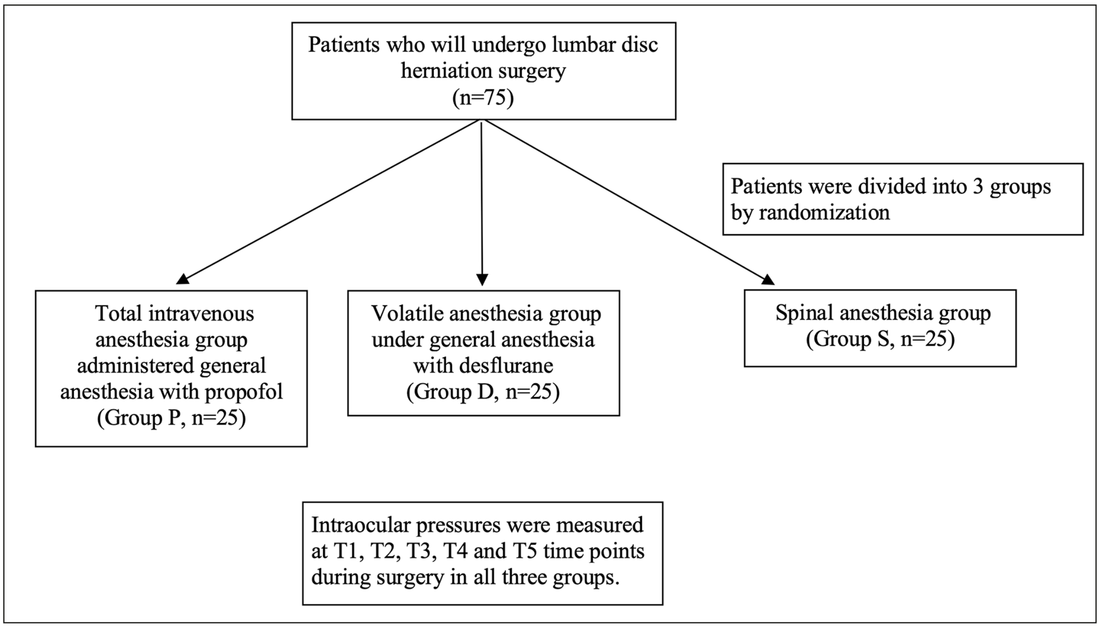

Figure 1. Flow chart of the study.

Table II. Measurement parameters of groups with regard to methods of anesthesia.

Variables	Methods of anesthesia			*p* (between groups)
	Desflurane (n = 25)	Propofol (n = 25)	Spinal (n = 25)	
Hemoglobin				
Preoperative	13.62 ± 1.59	13.48 ± 1.95	13.80 ± 1.99	0.838
Postoperative	12.82 ± 1.82	12.97 ± 1.85	13.32 ± 1.90	0.633
p (within groups)	**< 0.001**	**< 0.001**	**< 0.001**	
Hematocrit				
Preoperative	40.85 ± 4.42	40.18 ± 5.19	42.16 ± 5.67	0.383
Postoperative	39.12 ± 5.00	38.76 ± 5.45	41.01 ± 5.83	0.299
p (within groups)	**< 0.001**	**0.003**	**0.015**	
Intraoperative fluid	1,000 (800 - 1100)[a]	1,000 (900 - 1200)[a]	750 (600 - 850)[b]	**< 0.001**
Duration of operation, min	60 (45 - 65)[a]	60 (50 - 70)[a]	50 (40 - 55)[b]	**0.001**
Intraocular pressure				
T1	12.52 ± 5.81	14.60 ± 6.03	16.28 ± 5.74	0.083
T2	15.92 ± 7.99	19.24 ± 7.72*	15.76 ± 6.62	0.184
T3	18.20 ± 6.54*[a]	25.76 ± 7.90*[b]	21.00 ± 6.38*[ab]	**0.001**
T4	24.84 ± 7.97*	26.92 ± 9.93*	25.12 ± 6.95*	0.637
T5	19.04 ± 7.37*	17.88 ± 6.77	16.48 ± 6.72	0.432
p (within groups)	**< 0.001**	**< 0.001**	**< 0.001**	
End tidal CO_2				
T2	34 (32 - 36)	35 (35 - 36)	-	0.130
T3	31 (30 - 33)	35 (34 - 35)	-	**< 0.001**
T4	30 (30 - 33)	35 (34 - 36)	-	**< 0.001**
T5	32 (30 - 33)	36 (35 - 36)	-	**< 0.001**
Heart rate				
T1	83.40 ± 13.67	76.12 ± 19.22	75.76 ± 12.15	0.145
T2	85.64 ± 12.96[a]	89.44 ± 16.12*[a]	75.44 ± 13.39[b]	**0.003**
T3	72.84 ± 12.73*	80.32 ± 18.09	74.28 ± 11.58	0.158
T4	68.64 ± 14.84*	73.88 ± 15.46	72.92 ± 9.98	0.357
T5	72.04 ± 15.66*	70.96 ± 15.49	73.12 ± 11.95	0.870
p (within groups)	**< 0.001**	**< 0.001**	0.907	
Bispectral index				
T2	47.00 ± 3.81	45.28 ± 2.91	-	0.079
T3	45.04 ± 3.01	45.36 ± 2.50	-	0.684
T4	46.56 ± 5.23	45.80 ± 3.16	-	0.538
T5	52.04 ± 4.83	50.20 ± 3.85	-	0.143
Mean arterial pressure				
T1	104.80 ± 19.26	104.40 ± 13.00	106.00 ± 14.87	0.934
T2	96.60 ± 18.07	96.28 ± 20.81	99.72 ± 11.54	0.739
T3	84.36 ± 16.21*[a]	96.92 ± 17.82[b]	95.92 ± 14.35[b]	**0.013**
T4	81.12 ± 14.96*[a]	80.08 ± 12.06*[a]	90.76 ± 9.54*[b]	**0.005**
T5	94.84 ± 18.33*	91.68 ± 15.21*	94.12 ± 14.30*	0.767
p (within groups)	**< 0.001**	**< 0.001**	**0.001**	
Body temperature				
T1	36.5 (36.2 - 36.7)	36.5 (36.3 - 36.7)	36.6 (36.5 - 36.7)	0.232
T2	36.4 (36.2 - 36.5)[a]	36.4 (36.3 - 36.6)[ab]	36.6 (36.4 - 36.7)[b]	**0.029**
T3	36.2 (36.0 - 36.3)*[a]	36.4 (36.2 - 36.4)*[ab]	36.5 (36.3 - 36.6)*[b]	**< 0.001**
T4	35.7 (35.6 - 36.0)*[a]	35.7 (35.4 - 36.1)*[a]	36.4 (36.1 - 36.5)*[b]	**< 0.001**
T5	36.3 (36.1 - 36.5)	36.3 (36.2 - 36.4)*	36.4 (36.3 - 36.5)*	0.251
p (within groups)	**< 0.001**	**< 0.001**	**< 0.001**	

Data are given as mean ± standard deviation or median (1st quartile-3rd quartile) for continuous variables according to normality of distribution and as frequency (percentage) for categorical variables. *: Significantly different from T1 (within groups analysis of repeated measurements). [a,b]Denote pairwise comparison results of between groups analysis; if two groups have the same letter, that means there is no significant difference between them.

groups ($p = 0.013$), while MAP at T4 was notably higher in the spinal group compared to the other groups ($p = 0.005$). No significant differences were observed between groups with respect to T1, T2, and T5 MAP (Table II).

All groups demonstrated a decreasing trend of body temperature values from baseline to T5. T2 body temperature was significantly higher in the spinal group than in the desflurane group ($p = 0.029$). T3 body temperature was significantly higher in the spinal group than in the desflurane group ($p < 0.001$). T4 body temperature was significantly higher in the spinal group than in the other groups ($p < 0.001$, Table II).

Table III. Association between factors and T3 intraocular pressure, linear regression analysis results.

Variables	Univariable			Multivariable		
	Unstandardized coefficients (95% CI)	Standardized coefficients	*p*	Unstandardized coefficients (95% CI)	Standardized coefficients	*p*
Age	0.022 (-0.097 - 0.141)	0.044	0.709			
Sex, Male	0.876 (-2.919 - 4.671)	0.054	0.647			
Body mass index, kg/m^2	0.158 (-0.259 - 0.575)	0.088	0.452			
Comorbidities	0.033 (-3.544 - 3.610)	0.002	0.985			
Hypertension	-1.870 (-5.373 - 1.633)	-0.124	0.291			
Diabetes mellitus	4.607 (0.104 - 9.110)	0.232	**0.045**	4.758 (0.929 - 8.587)	0.240	**0.016**
Coronary artery disease	7.306 (-1.473 - 16.084)	0.191	0.102			
COPD	-3.859 (-11.606 - 3.888)	-0.115	0.324			
ASA classification	0.200 (-2.836 - 3.235)	0.015	0.896			
Hemoglobin, Preoperative	-0.005 (-0.968 - 0.957)	-0.001	0.991			
Hematocrit, Preoperative	-0.011 (-0.355 - 0.334)	-0.007	0.951			
Intraocular pressure, T1	0.475 (0.201 - 0.748)	0.376	**0.001**	0.451 (0.199 - 0.703)	0.357	**0.001**
Heart rate, T3	-0.011 (-0.132 - 0.110)	-0.022	0.853			
Mean arterial pressure, T3	0.055 (-0.048 - 0.158)	0.124	0.291			
Body temperature, T3	-0.346 (-6.247 - 5.554)	-0.014	0.907			
Methods of anesthesia[(1)]						
Desflurane	-7.560 (-11.493 - -3.627)	-0.474	**< 0.001**	-6.622 (-10.206 - -3.038)	-0.416	**< 0.001**
Spinal	-4.760 (-8.693 - -0.827)	-0.299	**0.018**	-5.708 (-9.282 - -2.133)	-0.358	**0.002**
Adjusted R^2	-			0.309		
Regression model	-			$F = 9.288$, $p < 0.001$		

[(1)]Reference category: Propofol, CI: Confidence interval.

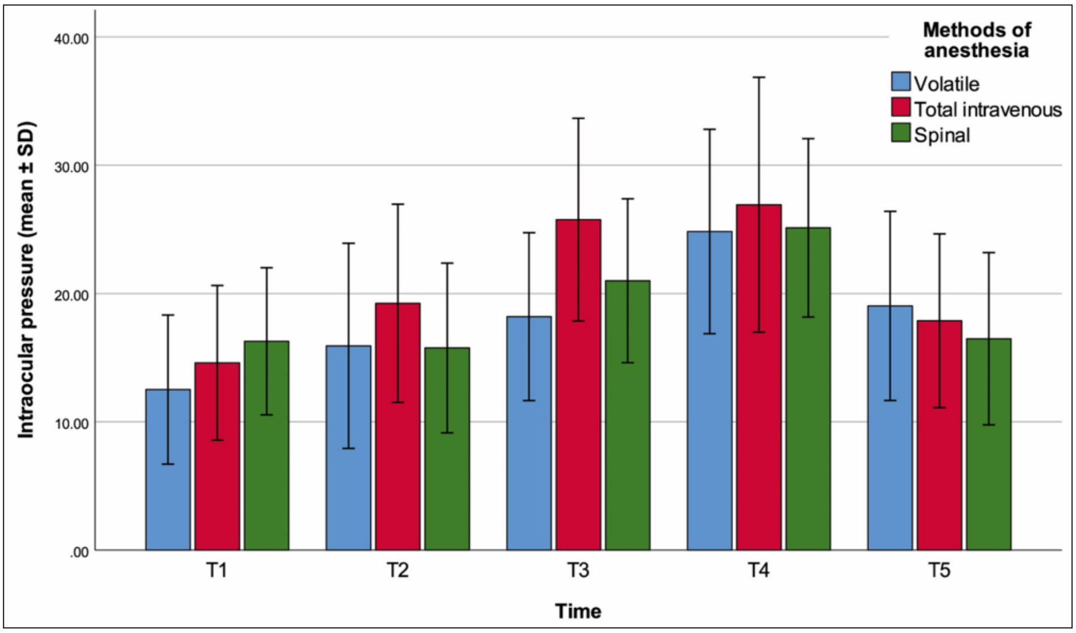

Figure 2. Intraocular pressure (mean ± standard deviation) with regard to time and group.

Multivariable linear regression analysis revealed that diabetes mellitus ($p = 0.016$) and high T1 IOP ($p = 0.001$) were independently associated with having higher IOP at T3. In addition, after adjusting for these two parameters, we found that the desflurane ($p < 0.001$) and spinal ($p = 0.002$)

1412

groups had lower T3 IOP compared to the propofol group (Table III). However, we found that none of the parameters analyzed were independently associated with T4 IOP (late prone) (Table IV).

Discussion

General anesthesia remains the prevailing choice for anesthesia in spinal interventions. The selection of anesthesia type is typically based on evaluations made by the surgeon and/or anesthesiologist. Factors taken into account include the patient's positioning during the procedure, their clinical status, the specific features of the intervention site, and the scope as well as the duration of the operation[16]. However, none of the examined parameters were found to be independently associated with T4 (late prone) IOP values. The changes in hemodynamics and other parameters associated with anesthesia monitoring were as anticipated.

In the supine position, significant decreases in IOP have been reported after induction and maintenance of anesthesia with both sevoflurane and propofol[17], while in the prone position, the IOP value has been reported to increase with both propofol use and desflurane/sevoflurane[18]. In the study by Pinar et al[19], increasing IOP values were noted over time as patients transitioned to the prone position in both the spinal and general anesthesia groups, with higher values observed in the general anesthesia group. In a cross-sectional study evaluating the effect of different surgical positions on IOP, it was reported that IOP values during prone positioning were significantly higher than IOP 10 minutes after anesthesia[20]. An investigation into patients undergoing lumbar spine surgery in the prone position revealed that the IOP levels of individuals demonstrated an elevation following adoption of the prone position, regardless of anesthesia type[21]. Anesthesia induction also appears to have an effect on IOP changes, since it has been reported that IOP values decrease after induction but increase during later stages of surgery (1 to 3 hours after prone positioning)[22]. Similarly, in this study, it was found that IOP values increased at 10 and 30 minutes after prone positioning and decreased after returning to the supine position.

Before adjusting for factors independently associated with IOP values, we found that early-prone IOP values were significantly lower in the desflurane anesthesia group compared to the propofol group. After adjusting for diabetes mellitus and baseline IOP, we found that recipients of desflurane anesthesia and spinal anesthesia had lower early prone IOP compared to the propofol group. In another study[19], it was reported that the IOP value after the prone position was lower in patients who underwent spinal anesthesia compared to those who received general anesthesia. Similarly, a prior study[21] had shown

Table IV. Association between factors and T4 intraocular pressure, linear regression analysis results.

	Univariable		
Variables	**Unstandardized coefficients (95% CI)**	**Standardized coefficients**	***p***
Age	0.036 (-0.095 - 0.166)	0.064	0.587
Sex, Male	1.918 (-2.235 - 6.071)	0.107	0.360
Body mass index, kg/m^2	0.132 (-0.326 - 0.591)	0.067	0.567
Comorbidities	0.656 (-3.273 - 4.584)	0.039	0.740
Hypertension	1.532 (-2.331 - 5.396)	0.092	0.432
Diabetes mellitus	-0.014 (-5.102 - 5.075)	-0.001	0.996
Coronary artery disease	5.250 (-4.502 - 15.002)	0.125	0.287
COPD	3.563 (-4.968 - 12.095)	0.097	0.408
ASA classification	1.533 (-1.785 - 4.850)	0.107	0.360
Hemoglobin, Preoperative	0.564 (-0.486 - 1.613)	0.124	0.288
Hematocrit, Preoperative	0.162 (-0.215 - 0.539)	0.100	0.395
Intraocular pressure, T1	0.250 (-0.069 - 0.569)	0.180	0.122
Heart rate, T4	-0.047 (-0.189 - 0.094)	-0.078	0.507
Mean arterial pressure, T4	-0.089 (-0.235 - 0.057)	-0.140	0.230
Body temperature, T4	-1.446 (-6.297 - 3.406)	-0.069	0.554
Methods of anesthesia[(1)]			
Desflurane	-2.080 (-6.802 - 2.642)	-0.119	0.383
Spinal	-1.800 (-6.522 - 2.922)	-0.103	0.450

[(1)]Reference category: Propofol, CI: Confidence interval.

that patients undergoing lumbar spine surgery in the prone position displayed higher IOP levels when subjected to general anesthesia compared to those who received spinal anesthesia. Sugata et al[18] described that the selection between sevoflurane and propofol did not lead to significant alterations in IOP changes during prone spine surgery. It appears that spinal and desflurane anesthesia can be preferred for prone-position surgical procedures in order to maintain IOP values within tolerable ranges.

A plausible mechanism contributing to the rise in IOP, even without external pressure on the eyeball, involves disrupted autoregulation, leading to an escalation in intraocular blood volume. Any change in MAP results in insufficient oxygenation of the optic nerve, resulting in ischemic injury. The perfusion pressure of the optic nerve decreases significantly with increasing IOP. It is important to understand the change in IOP in the prone anesthetized patient, as an increase in IOP could limit perfusion even in the presence of normal MAP[23], potentially leading to ischemic optic neuropathy, retinal artery occlusion, and blindness[24]. In a study[19] conducted with patients who underwent lumbar disc surgery in the prone position, general anesthesia, and spinal anesthesia recipients had similar MAP values measured before and after the prone position. Nonetheless, propofol-based general anesthesia has been suggested to cause lower HR and MAP after induction and intubation compared to desflurane anesthesia[25]. In this study, we found that MAP values decreased significantly from baseline in all groups. The MAP value at early prone (T3) was significantly lower in the desflurane anesthesia group compared to the other groups, whereas the late-prone MAP value was significantly higher in the spinal group compared to the other groups. Therefore, although monitoring MAP remains as an important method to prevent adverse ophthalmologic outcomes, further studies are required to determine better methods to assess IOP during prone positioning.

The prone position can present unique hemodynamic challenges. Compression of the abdomen can restrict blood flow and may increase bleeding at the surgical site. When postural hypotension and decreased cardiac function occur, HR, blood loss, and fluid support should be closely monitored[3]. In a study conducted with patients who underwent lumbar disc hernia operation, it was reported that general anesthesia and spinal anesthesia groups were similar in terms of hemodynamic parameters before and after prone positioning[19]. In another study[26] in which spinal surgery was performed, it was reported that HR in the post-anesthesia care unit was higher in general anesthesia recipients. Finsterwald et al[10] reported that spinal anesthesia required less volume support and intraoperative vasopressor treatment, as well as fewer transfusions compared to general anesthesia, which is supported by other studies[27]. Additionally, among patients undergoing spinal surgery, mean blood loss, intraoperative maximum blood pressure, and HR changes were reported to be lower with spinal anesthesia compared to general anesthesia[27]. There are other studies[28] reporting a lower HR for spinal anesthesia than for general anesthesia. However, despite describing some differences favoring spinal anesthesia with respect to the incidence of intraoperative hypertension and tachycardia, meta-analyses[12,15] on this topic have reported largely similar findings in general and spinal anesthesia. In the current study, we found that postoperative hemoglobin and hematocrit levels decreased significantly compared to the preoperative period, and the averages of hemoglobin and hematocrit of the anesthesia groups were similar in terms of HR averages; values measured after prone position were similar between anesthesia groups. Although no significant differences were found between the groups in terms of hemoglobin, hematocrit, and HR, it can be thought that hemodynamic instability was better provided in the spinal anesthesia group based on the result that intraoperative fluid requirement was lower in the spinal anesthesia group than in the other groups.

The $EtCO_2$ values after prone positioning were significantly higher in the propofol group than in the desflurane group. However, the $EtCO_2$ values detected in the study were always within the mild hypercapnia range (30-35 mmHg). Mild hypercapnia offers advantageous effects on cardiorespiratory, gastrointestinal, and neurological factors. These effects, whether direct or indirect, can lead to improved post-operative status and a shorter hospitalization period[29]. Likewise, in terms of BIS, we found that the state of consciousness and the depth of anesthesia in the desflurane and propofol groups were sufficient compared to the values in the literature[30]. Although the body temperature values showed minor differences between groups, they all remained within the normal range of 36.0-37.5°C for surgical conditions[31]. It can be said that all three anesthesia methods have tolerable effects on respiratory function, depth of anesthesia, and body temperature when evaluated in this context. In addition, the fact that these values were within normal limits and similar between the groups standardized the external factors that may affect intraocular pressure values and made the results more meaningful in the present study.

Awareness of the pathophysiology and linked risks related to prone spinal surgery is crucial to exploring preventive strategies and predictable treatment choices[32]. Various strategies can be used to prevent the increase in IOP that may cause vision loss. It may be prudent to check the orbital region every 15-20 minutes in case of compression[2], and careful preparation must be ensured to prevent external pressure to the eyes[24]. Anesthesiologists and surgeons should possess an understanding of factors that could potentially reduce ocular blood flow, leading to an elevated risk of postoperative vision loss. It is crucial to select anesthesia based on this awareness[33].

Limitations

The results should be interpreted with caution, as the study was performed at a single center with limited patient counts in each group. One of the limitations of the study is that the trend of change in the IOP measurement over a larger time period was not evaluated with a larger number of measurements. Despite these limitations, this study is valuable because it presents detailed results of three different anesthesia techniques.

Conclusions

The IOP value after the prone position is lower in spinal surgery cases performed with spinal and desflurane anesthesia compared to propofol anesthesia. However, all methods provide good perioperative hemodynamic stability, with marginal improvements observed with spinal anesthesia. It will be useful to test the results obtained in larger studies.

Conflict of Interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Ethics Approval

This study was conducted in accordance with the Declaration of Helsinki of 1975 (as revised in 2013), and Giresun University Faculty of Medicine Ethics Committee approved the study (approval number: KAEK: 04/2020).

Acknowledgments

Special thanks to Prof. Dr. Özgün Apan, Prof. Dr. Alpaslan Apan, and Prof. Dr. Yaşar Küçüksümer.

Informed Consent

All subjects provided written informed consent for inclusion before they participated in the study.

ORCID ID

Elvan Tekir Yılmaz: 0000-0001-8631-2520
Bilge Olgun Keleş: 0000-0002-8912-6317.

Availability of Data and Materials

All data presented in this article are included in the manuscripts or tables/figures. Further inquiries can be directed to the corresponding author.

Authors' Contributions

Study conception and design: ETY, BK; collection of data: ETY, BK; statistical analysis: ETY, BK; interpretation of data/results: all authors; manuscript drafting: ETY, BK; all the authors read and approved the manuscript for submission.

ClinicalTrials gov ID

NCT06070480.

References

1) Kwee MM, Ho YH, Rozen WM. The prone position during surgery and its complications: a systematic review and evidence-based guidelines. Int Surg 2015; 100: 292-303.
2) Cunha PD, Barbosa TP, Correia G, Silva R, Cruz Oliveira N, Varanda P, Direito-Santos B. The ideal patient positioning in spine surgery: a preventive strategy. EFORT Open Rev 2023; 8: 63-72.
3) DePasse JM, Palumbo MA, Haque M, Eberson CP, Daniels AH. Complications associated with prone positioning in elective spinal surgery. World J Orthop 2015; 6: 351-359.
4) Hunt K, Bajekal R, Calder I, Meacher R, Eliahoo J, Acheson JF. Changes in Intraocular Pressure in Anesthetized Prone Patients. J Neurosurg Anesthesiol 2004; 16: 287-290.
5) Roth S. Perioperative visual loss: what do we know, what can we do? Br J Anaesth 2009; 103: 31-40.
6) Chang CY, Chien YJ, Wu MY. Attenuation of increased intraocular pressure with propofol anesthesia: A systematic review with meta-analysis and trial sequential analysis. J Adv Res 2020; 24: 223-238.

7) Epstein NE. Perioperative visual loss following prone spinal surgery: A review. Surg Neurol Int 2016; 7: 347-360.

8) Nickels TJ, Manlapaz MR, Farag E. Perioperative visual loss after spine surgery. World J Orthop 2014; 5: 100-106.

9) Yamada MH, Takazawa T, Iriuchijima N, Horiuchi T, Saito S. Changes in intraocular pressure during surgery in the lateral decubitus position under sevoflurane and propofol anesthesia. J Clin Monit Comput 2016; 30: 869-874.

10) Finsterwald M, Muster M, Farshad M, Saporito A, Brada M, Aguirre JA. Spinal versus general anesthesia for lumbar spine surgery in high risk patients: Perioperative hemodynamic stability, complications and costs. J Clin Anesth 2018; 46: 3-7.

11) Ren JG, Cai B, Wang H, Wang XL, Cai DS. Effect of methoxymine on prevention and treatment of myocardial injury and cardiac function in elderly patients with hypotension during intraspinal anesthesia. Eur Rev Med Pharmacol Sci 2023; 27: 11755-11763.

12) De Cassai A, Geraldini F, Boscolo A, Pasin L, Pettenuzzo T, Persona P, Munari M, Navalesi P. General anesthesia compared to spinal anesthesia for patients undergoing lumbar vertebral surgery: a meta-analysis of randomized controlled trials. J Clinical Med 2020; 10: 102.

13) Attari MA, Mirhosseini SA, Honarmand A, Safavi MR. Spinal anesthesia versus general anesthesia for elective lumbar spine surgery: A randomized clinical trial. J Res Med Sci 2011; 16: 524-529

14) Lee JK, Park JH, Hyun SJ, Hodel D, Hausmann ON. Regional Anesthesia for Lumbar Spine Surgery: Can It Be a Standard in the Future? Neurospine 2021; 18: 733-740.

15) Meng T, Zhong Z, Meng L. Impact of spinal anaesthesia vs. general anaesthesia on peri-operative outcome in lumbar spine surgery: a systematic review and meta-analysis of randomised, controlled trials. Anaesthesia 2017; 72: 391-401.

16) Mergeay M, Verster A, Van Aken D, Vercauteren M. Regional versus general anesthesia for spine surgery. A comprehensive review. Acta Anaesthesiol Belg 2015; 66: 1-9.

17) Sator-Katzenschlager S, Deusch E, Dolezal S, Michalek-Sauberer A, Grubmüller R, Heinze G, Wedrich A. Sevoflurane and propofol decrease intraocular pressure equally during non-ophthalmic surgery and recovery. Br J Anaesth 2002; 89: 764-766.

18) Sugata A, Hayashi H, Kawaguchi M, Hasuwa K, Nomura Y, Furuya H. Changes in intraocular pressure during prone spine surgery under propofol and sevoflurane anesthesia. J Neurosurg Anesthesiol 2012; 24: 152-156.

19) Pınar HU, Kaşdoğan ZEA, Başaran B, Çöven İ, Karaca Ö, Doğan R. The effect of spinal versus general anesthesia on intraocular pressure in lumbar disc surgery in the prone position: A randomized, controlled clinical trial. J Clin Anesth 2018; 46: 54-58.

20) Sun Y, Wang J, Wang W, Fan G, Wu S, Zhao F, Lu Y, Liu D, Li Y, Hu J, Yang L, Bai Y, Zhao T, Zhao Y. Effect of different surgical positions on intraocular pressure: a cross-sectional study. BMC Ophthalmol 2022; 22: 318.

21) Lyzohub M. Intraocular pressure investigation during lumbar spine surgery in prone position. ScienceRise: Medical Science 2017; 11: 28-30.

22) Yiğit MA, Erkal KH, Ünlü EH, Bilen MK, Çevik B. Intraocular Pressure Changes in Prone Position and Affecting Factors. South Clin Ist Euras 2023; 34: 125-130.

23) Cheng MA, Todorov A, Tempelhoff R, McHugh T, Crowder CM, Lauryssen C. The effect of prone positioning on intraocular pressure in anesthetized patients. Anesthesiology 2001; 95: 1351-1355.

24) Kaur K, Khanduri N, Sachdeva S, Singh R, Bhardwaj M, Bala M. A study to evaluate ocular changes in patients undergoing spine surgery in the prone position. J Anaesthesiol Clin Pharmacol 2021; 37: 580-585.

25) Ozkose Z, Ercan B, Unal Y, Yardim S, Kaymaz M, Dogulu F, Pasaoglu A. Inhalation versus total intravenous anesthesia for lumbar disc herniation: comparison of hemodynamic effects, recovery characteristics, and cost. J Neurosurg Anesthesiol 2001; 13: 296-302.

26) Jellish WS, Thalji Z, Stevenson K, Shea J. A prospective randomized study comparing short-and intermediate-term perioperative outcome variables after spinal or general anesthesia for lumbar disk and laminectomy surgery. Anesth Analg 1996; 83: 559-564.

27) Attari MA, Mirhosseini SA, Honarmand A, Safavi MR. Spinal anesthesia versus general anesthesia for elective lumbar spine surgery: A randomized clinical trial. J Res Med Sci 2011; 16: 524-529.

28) Kahveci K, Doger C, Ornek D, Gokcinar D, Aydemir S, Ozay R. Perioperative outcome and cost-effectiveness of spinal versus general anesthesia for lumbar spine surgery. Neurol Neurochir Pol 2014; 48: 167-173.

29) Saghaei M, Matin G, Golparvar M. Effects of intra-operative end-tidal carbon dioxide levels on the rates of post-operative complications in adults undergoing general anesthesia for percutaneous nephrolithotomy: A clinical trial. Adv Biomed Res 2014; 3: 84.

30) Struys M, Versichelen L, Byttebier G, Mortier E, Moerman A, Rolly G. Clinical usefulness of the bispectral index for titrating propofol target effect-site concentration. Anaesthesia 1998; 53: 4-12.

31) Burger L, Fitzpatrick J. Prevention of inadvertent perioperative hypothermia. Br J Nurs 2009; 18: 1114-1119.

32) Stambough JL, Dolan D, Werner R, Godfrey E. Ophthalmologic complications associated with prone positioning in spine surgery. J Am Acad Orthop Surg 2007; 15: 156-165.

33) Kamming D, Clarke S. Postoperative visual loss following prone spinal surgery. Br J Anaesth 2005; 95: 257-260.