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Original Research Article

Changes in optic nerve sheath diameter and intraocular pressure as a surrogative marker of postoperative visual loss in patients undergoing surgery in prone position– Prospective observational study

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Abstract

Background: Postoperative visual loss is a devastating complication that can occur following prone surgery. One of the significant causes of postoperative visual loss is ischemic optic neuropathy. This study aimed to investigate the effects of the prone position on intraocular pressure (IOP) and optic nerve sheath diameter (ONSD), which could serve as potential markers for postoperative visual loss.

Methods: Forty-seven patients who met the inclusion criteria were included in the study, and their intraocular pressure (IOP) and optic nerve sheath diameter (ONSD) were measured at five different time points: T0 (awake patient in the supine position), T1 (ten minutes after induction of general anesthesia in the supine position), T2 (ten minutes after assuming the prone position during surgery), T3 (at the end of surgery in the prone position), and T4 (ten minutes before extubation after repositioning to the supine position). The data collected were analyzed using one-sample t-tests and linear regression analysis to assess the variations in IOP and ONSD.

Results: The study included 22 male participants (46.8%) and 25 female participants (53.2%), with a mean age of 44.2 ± 9.7 years. The total duration of prone positioning during surgery was 152 ± 27 minutes. Both IOP and ONSD were found to be significantly higher in the prone position at T3 compared to the supine position at T1 ($p = 0.00$). Additionally, a positive linear correlation was observed between the duration of prone positioning and the increase in IOP, with an r-value of 0.386.

Conclusions: Prone positioning during surgery is associated with significant increases in both intraocular pressure and optic nerve sheath diameter, which may contribute to the risk of postoperative visual loss. Preventive measures should be implemented to monitor and manage these factors during prone surgeries to reduce the risk of postoperative visual loss.

Keywords: Intraocular pressure, Optic nerve sheath diameter, Postoperative visual loss.

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1. Introduction

Post-operative visual loss is a rare dreadful complication that is commonly reported in surgeries requiring the prone position.[1,2] The incidence of postoperative visual loss following prone spine surgery ranges from 0.013% to 1%.[3] Several factors, including blood loss, intraoperative hypotension, pressure on the globe and anaemia, lead to postoperative visual loss.[4] Ischemic optic neuropathy is the most common cause of optic neuropathy.[5,6] Ho et al reported that ischemic optic neuropathy occurs after spinal cord surgery in the prone position and that the external part of the nerve is commonly affected by ischemia and is frequently

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bilateral (40% for Anterior Ischemic Optic Neuropathy (AION) and 47% for Posterior Ischemic Optic Neuropathy (PION).[7] Lam et al reported that the intra ocular pressure increased from 13.5 mmHg in the supine position to 20 mmHg in the prone position.[8] The glymphatic system regulates CSF transport from the retina, optic nerve and brain. Acute change in rapid eye movement, body position and anesthesia can impair the glymphatic system leading to accumulation of CSF.[9-11] Hence, we hypothesised that when patients are positioned in the prone position during surgery, both intraocular pressure and optic nerve sheath diameter increase. These changes could potentially serve as valuable tools to predict and prevent postoperative visual loss by providing early indicators of pressure-related damage to the optic nerve.

2. Materials and Methods

This prospective observational study was conducted between April 2022 and March 2023 at a tertiary care referral institute. After receiving approval from the Institute Ethics Committee, the study was registered in the Clinical Trial Registry of India (CTRI/2022/02/040672).

The sample size was calculated based on the methods of Mahvash Agah et al., who reported mean intraocular pressures of 15.4 mmHg at baseline and 25.5 mmHg in the prone position, resulting in an effect size (E) of 10.1.[6] An α error of 5% (95% confidence level) and a power of 80% (β = 0.20) were assumed. Based on these parameters, the required sample size to detect paired differences in mean IOP was determined to be 47 subjects.

Written informed consent was obtained from patients classified as physical status 1 and 2 according to the American Society of Anesthesiologists, who were scheduled for prone surgeries. Patients with pre-existing eye diseases, a history of head or neck surgery, hemoglobin levels <10g/dL, anticipated blood loss exceeding one liter during prone surgery, or a history of severe anaphylaxis to ultrasound gel were excluded from the study.

In the preoperative assessment, patients underwent a comprehensive ophthalmologic examination, which included tests for visual acuity, color vision, slit-lamp examination of both the anterior and posterior segments, evaluation of extraocular movements, goniometry, and measurement of intraocular pressure in both eyes. Patients who met the inclusion criteria were then recruited into the study.

Once enrolled, each patient underwent a general physical examination, systemic examinations, and airway assessment. Preoperative fasting of a minimum of 8 hours was ensured before the operation. Intravenous fluids, such as Ringer's lactate, were administered at a rate of 2 mL/kg/hr. overnight during the fasting period.

To reduce anxiety and ensure sound sleep, all patients received 0.25 mg of alprazolam orally the night before surgery. Additionally, each patient received 150 mg of ranitidine in tablet form the previous night and again on the morning of surgery with sips of water.

All patients were clinically examined during the preoperative period and the entire procedure was explained and informed written consent was obtained. In operative room, standard intraoperative monitors such as an ECG, pulse oximeter, non-invasive blood pressure (NIBP) were attached to the patient, and baseline parameters was recorded. The patients were preoxygenated with 100% O_2 for 3 minutes after that anaesthesia was induced with fentanyl (2 µg/kg), propofol (2 mg/kg) and vecuronium (0.1 mg/kg). Following tracheal intubation, the patients were ventilated in volume control mode with a tidal volume of 8 mL/kg, a frequency of 12/min, and no positive end-expiratory pressure (PEEP)

The patients were then positioned in the prone position for the surgery with necessary safety precautions to avoid any pressure on the eyes. The head was placed in a horseshoe-shaped headrest to prevent direct contact or pressure on the eyes. Anesthesia was maintained with a mixture of O_2 and N_2O (1:2), and Isoflurane was titrated based on the Bispectral Index, maintaining it between 40-60. Vecuronium boluses were administered at a dose of 0.01 mg/kg every 30 minutes. The mean arterial blood pressure (MAP) was kept stable, with a maximum decrease of no more than 20% from the preinduction value. Controlled ventilation was maintained by targeting end-tidal CO_2 ($EtCO_2$) levels between 30 and 40 mmHg. Intraoperative fluid therapy was managed with crystalloids, with a maximum of 2 mL/kg/hr. throughout the procedure to prevent hemodilution. Any hypotension, defined as a decrease in MAP >20% from baseline, was treated with vasopressors such as ephedrine at titrated doses.

Both eyes were anesthetized with 0.5% tetracaine. Intraocular pressures (IOP) were measured using an I-C 100 hand-held applanation tonometer (Icare USA, Inc.). The mean of five measurements, with a standard deviation of less than 5%, was considered acceptable; otherwise, the measurement was repeated. The tonometer was calibrated before each measurement. IOP was measured bilaterally at five predefined time points: T0 (awake patient in the supine position), T1 (ten minutes after induction of general anaesthesia in the supine position), T2 (ten minutes after the patient reached the prone position), T3 (after surgical intervention in the prone position), and T4 (ten minutes before extubation, with the patient in the supine position).

The optic nerve sheath diameter (ONSD) in both eyes was measured at the same time points (T0 to T4) using a Sonosite portable ultrasound (Fujifilm, Sonosite Inc., USA) with a 12 MHz linear probe. A layer of acoustic gel was applied to the closed eyelids, and pressure on the globe was kept minimal to avoid affecting blood flow in the orbital blood vessels. The ONSD was measured 3 mm behind the optic disc, and three measurements were taken from each eye at various time points.

Simultaneously, peak airway pressure (Pmax), end-tidal isoflurane, end-tidal CO_2 ($EtCO_2$), heart rate, peripheral oxygen saturation (SpO_2), and mean arterial pressure (MAP) were monitored at each of the predefined time points. Postoperative visual assessment was conducted in the recovery room and 24 hours post-surgery, with patients being questioned about visual acuity or any visual disturbances. Pre- and postoperative hematocrit levels, as well as urine output and blood loss, were recorded. Patients who experienced more than 1 liter of blood loss during the surgery were excluded from the statistical analysis. (**Figure 1**)

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) software. Categorical variables, including gender and ASA score, were expressed as proportions. Categorical variables, including gender and ASA score, were expressed as proportions. Continuous variables, specifically age, height, weight, BMI, peak airway pressure (Pmax), end-tidal CO_2 ($EtCO_2$), intraocular pressure (IOP), optic nerve sheath diameter (ONSD), end-tidal isoflurane, and SpO2, were expressed as mean ± standard deviation. Mixed effect models were employed to investigate the influence of the duration of prone positioning on IOP and ONSD. These models account for correlated measurements within each patient due to multiple time points. To test the significance of continuous variables, paired t-tests and repeated measures of analysis of variance (ANOVA) were used. A p-value of less than 0.05 was considered statistically significant for all tests.

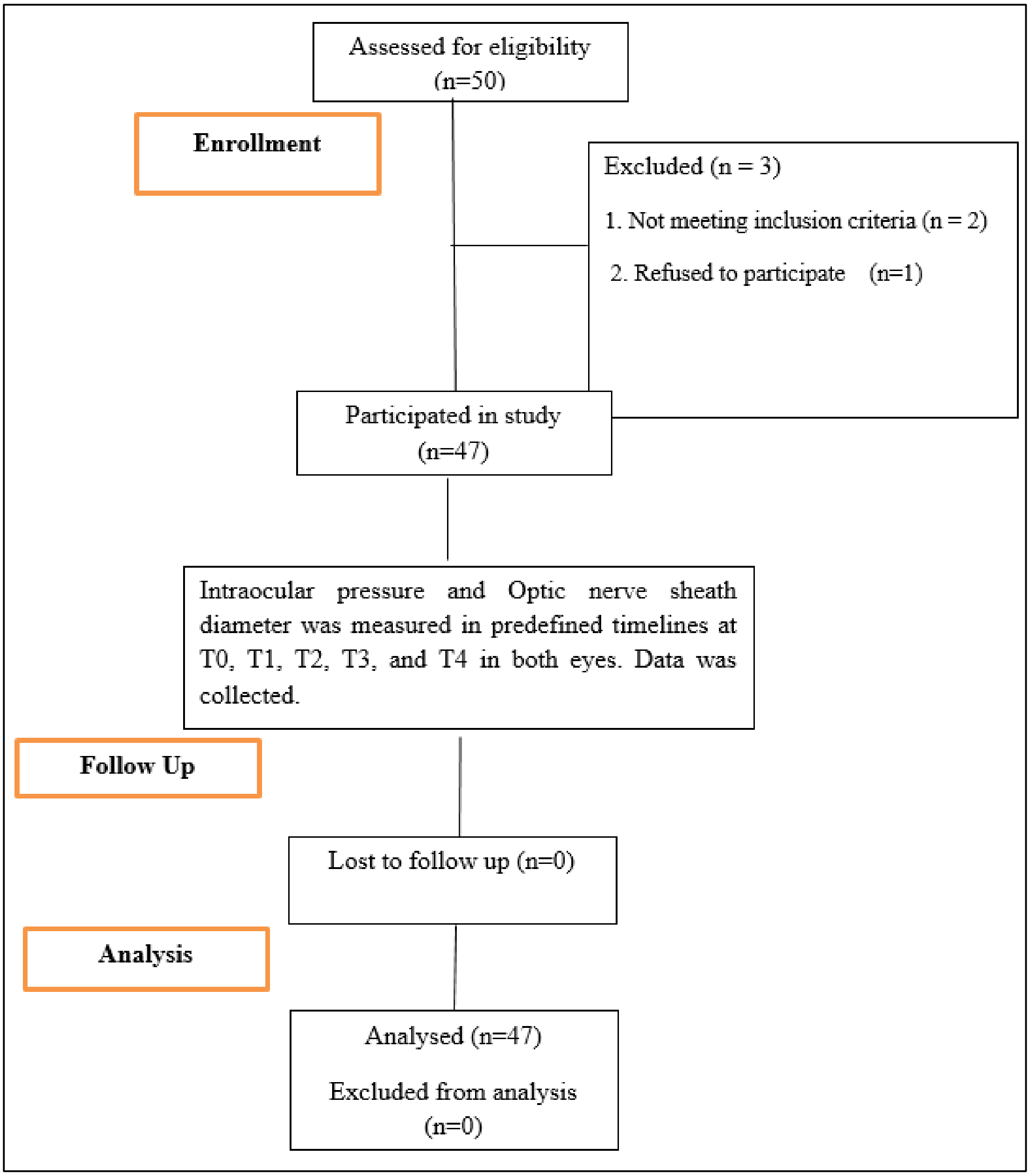

Figure 1: Consort flow diagram

3. Results

The demographic parameters, such as sex and ASA score, are presented as percentages (%) (**Table 1**). The mean intraocular pressure (IOP) and optic nerve sheath diameter (ONSD) for both eyes were measured at various time points and are expressed as means ± standard deviation (SD).

At time point T3, the mean IOP was 36.58 ± 1.51 mmHg, whereas at T1, it was 13.68 ± 4.83 mmHg. This indicates a significant increase in intraocular pressure when transitioning from the supine position to the prone position, with a p-value of 0.00 (**Table 2**).

Similarly, the mean optic nerve sheath diameter in the T3 position was 5.63 ± 0.24 mm, compared to 4.81 ± 0.26 mm in the T1 position. This demonstrates a significant increase in the optic nerve sheath diameter in the prone position, with a p-value of 0.00 (**Table 3**).

Linear regression analysis revealed a strong positive correlation between IOP and ONSD, with an r-value of 0.995 and a p-value of 0.00 (**Table 4**). Additionally, a linear relationship was observed between the duration of prone positioning and IOP, with an r-value of 0.386 (**Table 4**, **Figure 3**).

Table 1: Mean IOP of both eyes of the study participants in five occasions during surgery in the prone position

S. No.	Baseline parameters	Values Mean (SD)
1.	Mean age in years	44.2 (9.7)
2.	**Gender**	
	Male	22 (46.8%)*
	Female	25(53.2%)*
3.	Mean BMI	24.95 (2.03)
4.	**ASA physical status**	
	ASA – I	30 (63.8%)*
	ASA – II	17 (36.2%)*
5.	Mean of total duration of anaesthesia in minutes	175 (25)
6.	Mean of total duration in prone position (min)	152 (27)

*Values expressed in proportion n (%)

Table 2: Mean IOP of both eyes of the study participants in five occasions during surgery in the prone position

Occasions	Time Interval	Mean (Range), mmHg	SD	SE	95%CI for Mean	One sample T test	p-value
T0	10	12.57 (10.9 to 13.6)	0.679	0.09	12.05 to 12.45	123.6	
T1	10	13.68 (11.8 to 43.6)	4.83	0.704	12.26 to 15.09	19.4	
T2	10	25.48 (21.8 to 27.7)	1.51	0.220	25.03 to 25.92	115.6	
T3	10	36.58 (34.2 to 40.1)	1.51	0.221	36.1 to 37.0	165	0.00
T4	10	13.87 (11.6 to 15.5)	0.825	0.12	13.6 to 14.1	115.1	

*The values are expressed as the means ±SD. P value < 0.05 was considered significant.

Table 3: Mean ONSD of both eyes of the study participants in five occasions during surgery in the prone position

Occasions	Time Interval	Mean(Range), mm	SD	SE	95%CI for mean	One sample T test	p-value
T0	10	4.67(4.20 to 5.35)	0.26	0.38	4.59 to 4.74	121.3	
T1	10	4.81(4.36 to 5.55)	0.26	0.38	4.73 to 4.89	125.3	
T2	10	5.25(4.7 to 6.05)	0.25	0.37	5.17 to 5.33	138.7	
T3	10	5.63(5.15 to 6.28)	0.24	0.36	5.56 to 5.70	155.3	
T4	10	4.77 (4.36 to 5.58)	0.27	0.40	4.69 to 4.85)	119.4	0.00

*The values are expressed as the means ±SD. P-value < 0.05 was considered significant

Table 4: Linear regression analysis

Independent Variable	Dependent Variable	r	P
Duration of prone position	IOP	0.386	0.521
Duration of prone position	ONSD	0.399	0.506
IOP	ONSD	0.995	0.000
ONSD	IOP	0.995	0.000

A positive correlation and linear relationship are present

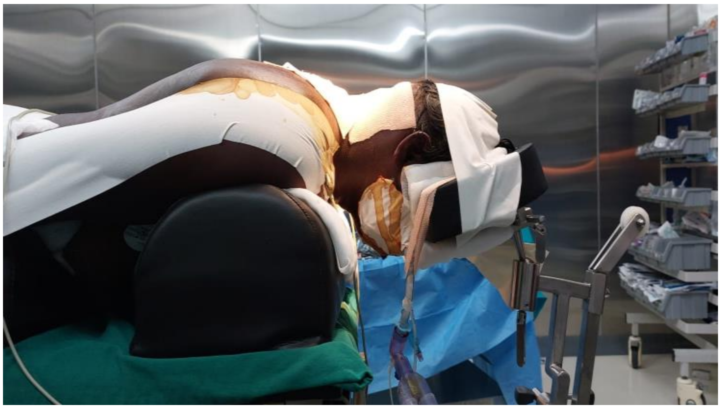

Figure 2: Patient in the prone position with horseshoe head rest

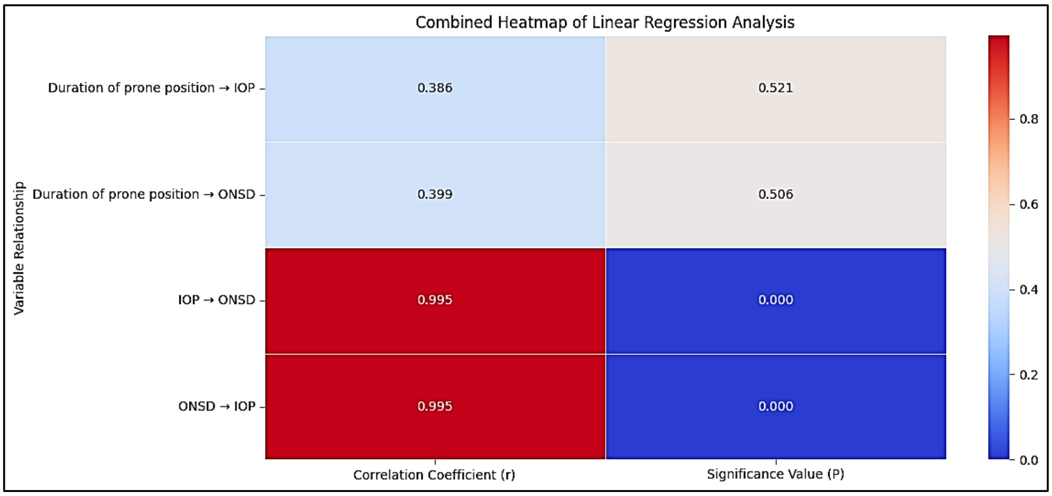

Figure 3: The heatmap illustrates the correlation coefficients (**r**) and significance values (**P**) for the relationships between variables. Strong correlations (e.g., IOP ↔ ONSD, **r = 0.995**) are shown in dark red, while moderate correlations (e.g., prone position ↔ IOP/ONSD) appear in lighter shades. Statistically significant relationships (**P = 0.000**) are highlighted in dark blue, while non-significant ones (**P > 0.05**) are in lighter shades

4. Discussion

In prone surgeries, the patient is positioned face-down on their abdomen with their head resting over soft gelatinous head ring or head pin holder. Postoperative vision loss occurs more frequently after prone surgery. Ischemic optic neuropathy (ION) causes postoperative visual loss by anterior or posterior and central retinal artery occlusion.[7] Although the pathophysiology of ION is not clearly understood, increased intraocular pressure compromises ocular perfusion pressure causing ischemia of the optic nerve and leading to ION.

In our study, intraocular pressure and optic nerve sheath diameter were significantly greater in prone position than in supine position (**Table 2**, **Table 3**). Agah et al evaluated intraocular pressure in the prone position among patients who underwent percutaneous nephrolithotomy. They report that the intraocular pressure significantly increased after 2 hours in prone position.[6] Similarly Lam et al reported that the intraocular pressure increased significantly in prone position, compromising ocular perfusion pressure and even maintaining normotension.[8]

During surgery, we used the ultrasound guided optic nerve sheath diameter along with IOP via a hand-held tonometer to measure the changes in the prone position. The optic nerve sheath diameter has been shown to be an important aid in detecting increased intracranial pressure.[9,12] In our study we measured the ultrasound guided optic nerve sheath diameter of both eyes at various timelines. We observed a time dependent increase in the optic nerve sheath diameter when the patient was transitioning from supine position to prone position, which was consistent in both eyes. (**Table 4**).

Numerous case reports in the literature have highlighted postoperative visual loss following prone surgery, often attributed to extraocular compression.[14,15] To mitigate the risk of extraocular compression, we employed a horseshoe-shaped headrest, ensuring the head was suspended in a neutral position for all patients during surgery (**Figure 2**). Surprisingly, our data revealed that factors beyond extraocular compression contributed to the increase in both intraocular pressure and optic nerve sheath diameter in the prone position (Tables 2, 3). These findings are consistent with a pilot study by Rahangdale et al., which reported a

20.7% increase in ONSD due to impaired clearance of cerebrospinal fluid (CSF) in the peri-optic space during prone spine surgery.[9]

To decrease intraoperative blood loss for spine surgery deliberate hypotension is advocated. However this hypotension may itself decrease ocular perfusion pressure leading to ischemia.[16] To avoid this complication, we refrained from inducing deliberate hypotension and instead maintained euvolemia in all our cases. The mean arterial pressure was maintained at more than 75mmHg throughout the surgery. Additionally, elevated arterial carbon dioxide levels can contribute to an increase in intraocular pressure (IOP) while patients are in the prone position under general anesthesia.[17,18] To mitigate this effect, we ensured that the end-tidal CO_2 ($EtCO_2$) remained within the normal range throughout the procedure, thereby minimizing its impact on ocular perfusion pressure.

A positive linear relationship was observed between intraocular pressure (IOP) and optic nerve sheath diameter (ONSD) when analysed using linear mixed models, with an r-value of 0.995 and p = 0.00 (**Table 4**). Similarly, Agah et al. investigated the effects of prone positioning on IOP and reported a significant linear relationship with an r-value of 0.67 and p = 0.01.[6]

Upon transitioning to the prone position, both IOP and ONSD significantly increased over time, but they returned to near baseline values in most of the patients. Fortunately, none of the patients experienced ocular injuries or visual loss during the postoperative period. Supportive padded headrests and head elevation are recommended measures to minimize inappropriate pressure on the face and eyes.[19]

There were several limitations in our study. Although it was a prospective study, we were unable to establish a cause-and-effect relationship between increased intraocular pressure (IOP) and optic nerve sheath diameter (ONSD) with postoperative visual loss. Instead, our focus was on isolating elevated IOP and ONSD, which could potentially compromise the ocular pressure gradient during prone positioning and predispose high-risk patients to postoperative visual loss.

Our results may not be applicable to other age groups, as our study population primarily consisted of middle-aged individuals. Additionally, a hand-held applanation tonometer was used to measure IOP during prone surgeries. However, this device has limitations, particularly in patients with increased corneal thickness, steep corneas, or corneal irregularities. Furthermore, it is expensive and requires specialized expertise to operate and accurately measure intraocular pressure.

Another limitation of our study was that we did not investigate possible factors that could mitigate the significant increases in IOP and ONSD. Nevertheless, our findings provide a foundation for future studies exploring strategies to reduce IOP and ONSD in prone-positioned patients.

5. Conclusion

A strong positive correlation exists between intraocular pressure (IOP) and optic nerve sheath diameter (ONSD) during prone position. This significant increase in IOP and ONSD may increase the risk of postoperative visual loss. Factors other than external compression, such as the prone position itself, contribute to these changes. Future research should focus on preventive strategies in prone position to reduce the risk of visual complications in high-risk patients.

6. Source of Funding

None.

7. Conflict of Interest

None.

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