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SCIENTIFIC ARTICLE

Changes in retinal nerve fiber layer thickness after spinal surgery in the prone position: a prospective study[☆]



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KEYWORDS

Retinal nerve fiber layer thickness;
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Intraocular pressure

Abstract

Background and objectives: Changes in ocular perfusion play an important role in the pathogenesis of ischemic optic neuropathy. Ocular perfusion pressure is equal to mean arterial pressure minus intraocular pressure. The aim of this study was to evaluate the changes in the intraocular pressure and the retinal nerve fiber layer thickness in patients undergoing spinal surgery in the prone position.

Methods: This prospective study included 30 patients undergoing spinal surgery. Retinal nerve fiber layer thickness were measured one day before and after the surgery by using optical coherence tomography. Intraocular pressure was measured by tonopen six times at different position and time-duration: supine position (baseline); 10 min after intubation (Supine 1); 10 (Prone 1), 60 (Prone 2), 120 (Prone 3) min after prone position; and just after postoperative supine position (Supine 2).

Results: Our study involved 10 male and 20 female patients with the median age of 57 years. When postoperative retinal nerve fiber layer thickness measurements were compared with pre-operative values, a statistically significant thinning was observed in inferior and nasal quadrants ($p=0.009$ and $p=0.003$, respectively). We observed a statistically significant intraocular pressure decrease in Supine 1 and an increase in both Prone 2 and Prone 3 when compared to the baseline. Mean arterial pressure and ocular perfusion pressure were found to be significantly lower in Prone 1, Prone 2 and Prone 3, when compared with the baseline.

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PALAVRAS-CHAVE

Espessura da camada de fibras nervosas da retina;
 Pronação;
 Cirurgia da coluna vertebral;
 Pressão Intraocular

Conclusions: Our study has shown increase in intraocular pressure during spinal surgery in prone position. A statistically significant retinal nerve fiber layer thickness thinning was seen in inferior and nasal quadrants one day after the spinal surgery.

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Alterações da espessura da camada de fibras nervosas da retina após cirurgia da coluna vertebral em pronação: estudo prospectivo

Resumo

Justificativa e objetivos: As alterações de perfusão ocular desempenham um papel importante na patogênese da neuropatia óptica isquêmica. A pressão de perfusão ocular é igual à pressão arterial média menos a pressão intraocular. O objetivo deste estudo foi avaliar as alterações da pressão intraocular e da espessura da camada de fibras nervosas da retina em pacientes submetidos à cirurgia da coluna vertebral em pronação.

Métodos: Este estudo prospectivo incluiu 30 pacientes submetidos à cirurgia da coluna vertebral. A espessura da camada de fibras nervosas da retina foi medida um dia antes e um depois da cirurgia, com o uso da tomografia de coerência óptica. A pressão intraocular foi medida seis vezes com o Tonopen e o tempo de duração em posições diferentes: em supinação (basal), 10 minutos após a intubação (Supinação 1); após a pronação aos 10 minutos (Pronação 1), 60 minutos (Pronação 2) e 120 minutos (Pronação 3) e logo após a supinação no período pós-operatório (Supinação 2).

Resultados: Nosso estudo envolveu 10 pacientes do sexo masculino e 20 do feminino, com média de 57 anos. No pós-operatório, quando as medidas da espessura da camada de fibras nervosas da retina foram comparadas com os valores do pré-operatório, um afinamento estatisticamente significativo da retina foi observado nos quadrantes nasais e inferiores ($p=0,009$ e $p=0,003$, respectivamente). Observamos uma diminuição da pressão intraocular estatisticamente significativa em Supinação 1 e um aumento em ambos momentos Pronação 2 e Pronação 3, em comparação com os valores basais. A pressão arterial média e a pressão de perfusão ocular foram significativamente mais baixas em Pronação 1, Pronação 2 e Pronação 3, em comparação com os valores basais.

Conclusões: Nosso estudo mostrou aumento da pressão intraocular durante a cirurgia da coluna vertebral em pronação. Um afinamento estatisticamente significativo da espessura da camada de fibras nervosas da retina foi observado nos quadrantes nasais e inferiores um dia após a cirurgia da coluna vertebral.

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Introduction

Postoperative vision loss (POVL) is a rare but serious complication that may develop after non-ocular surgeries.¹⁻³ POVL most commonly occurs after spinal surgery. The etiology of POVL has been identified as posterior ischemic optic neuropathy (PION), anterior ischemic optic neuropathy (AION) and central arterial occlusion, respectively.⁴⁻⁶ A multi-center study demonstrated that male gender, obesity, use of Wilson frame, long duration of anesthesia, excess blood loss and low ratio of colloids administration are the independent risk factors for peroperative ION development after spinal surgery.⁷ Changes in ocular perfusion play an important role in the pathogenesis of ischemic optic neuropathy.⁸ Ocular perfusion pressure (OPP) is calculated by the subtraction of intraocular pressure (IOP) from mean arterial pressure

(MAP).⁸ Several studies have demonstrated that spinal surgery in the prone position causes an IOP elevation.⁹⁻¹³ It has been speculated that as a result of IOP elevation in the prone position, OPP reduces (in patients where MAP remains stable or reduces) and may lead to AION.^{9,10,12}

Although IOP changes during spinal surgery in prone position have been well demonstrated, there is no study evaluating the effect of these changes on the optic nerve. Retinal nerve fiber layer thickness (RNFLT) is an important objective marker for early period changes due to optic nerve damage, which in turn is caused by ischemic optic neuropathy and sudden increase in IOP.¹⁴⁻¹⁸

In this prospective study, we aimed to determine the early period RNFLT changes in patients undergoing spinal surgery in the prone position and the factors affecting these changes.

Materials and methods

The study was performed with informed patient consent, and conducted under a protocol approved by the local Ethics Committee of Çanakkale Onsekiz Mart University (26.04.2012, 050-99-79) and in accordance with the ethical standards stated in the 1964 Declaration of Helsinki. Participants for the study were enrolled from consecutive patients who underwent spinal surgery between May and November 2012, and whose physical states were I-III in accordance with American Society of Anesthesiologists (ASA).

One day before the surgery, the patients underwent a full ophthalmic examination including visual acuity, slit-lamp exam, IOP measurement using Goldmann applanation tonometry and fundus examination. Patients under 18 year and patients with spherical values ± 5 dioptre and/or cylindrical values ± 3 dioptre refractory error, glaucoma, uveitis, history of eye surgery, optic nerve anomaly, history of allergy to topical anesthesia, or measurement quality below 5/10 on optic coherence tomography (OCT) were excluded.

The RNFLT were measured one day before and after the surgery by using OTI Spectral OCT/SLO (Ophthalmic Technologies Inc. (OTI), Toronto, Ontario, Canada). OCT scans were made after placing a 3.4mm diameter circular ring around the optic nerve head on image of the confocal scanning laser ophthalmoscopy. The patients' RNFLT maps were evaluated together with normative RNFLT ratios. The average RNFLT measurements for temporal, superior, nasal and inferior quadrants were collected (Fig. 1).

No premedication was given before anesthesia. Anesthesia was induced with 2 $\mu\text{g}/\text{kg}$ fentanyl, and 2.5 mg/kg propofol. Tracheal intubation was facilitated with 0.6 mg/kg rocuronium, and the lungs were mechanically ventilated at 0.5 FiO_2 . Anesthesia was maintained with sevoflurane, and remifentanyl 0.15–0.2 $\mu\text{g}/\text{kg}/\text{min}$. Additional rocuronium was administered as required. After topical anesthesia (right eye 0.5% proparacaine hydrochloride, 0.5% Alcaine, Alcon) IOP measurements were taken for six times with Tono-Pen AVIA applanation tonometer (Reichert Inc., Depew, NY): before premedication in the supine position (baseline); 10 min after intubation (Supine 1); 10 min (Prone 1), 60 min (Prone 2), 120 min (Prone 3) after being turned to prone position and 10 min after the patient was turned to supine position (Supine 2). Prone position cushions were used to stabilize the patients' heads in prone position.

Systolic blood pressure (SBP), diastolic blood pressure (DBP), MAP, heart rate (HR), end-tidal carbon dioxide (ET-CO_2) and oxygen saturation (SatO_2) were also recorded simultaneously with IOP measurements. OPP was calculated using the MAP-IOP formula. The anesthesia, prone position and surgery durations were also noted. The amount of blood and liquids given to the patient was measured against liquid loss and urine output during the operation to calculate liquid balance [liquid balance = (given blood + fluids) – (lost blood + urine)]. Preoperative and postoperative hemoglobin (Hb) and hemocrit (Htc) levels were recorded. In the recovery room, the patients were asked whether they had any vision loss or discomfort in their eyes.

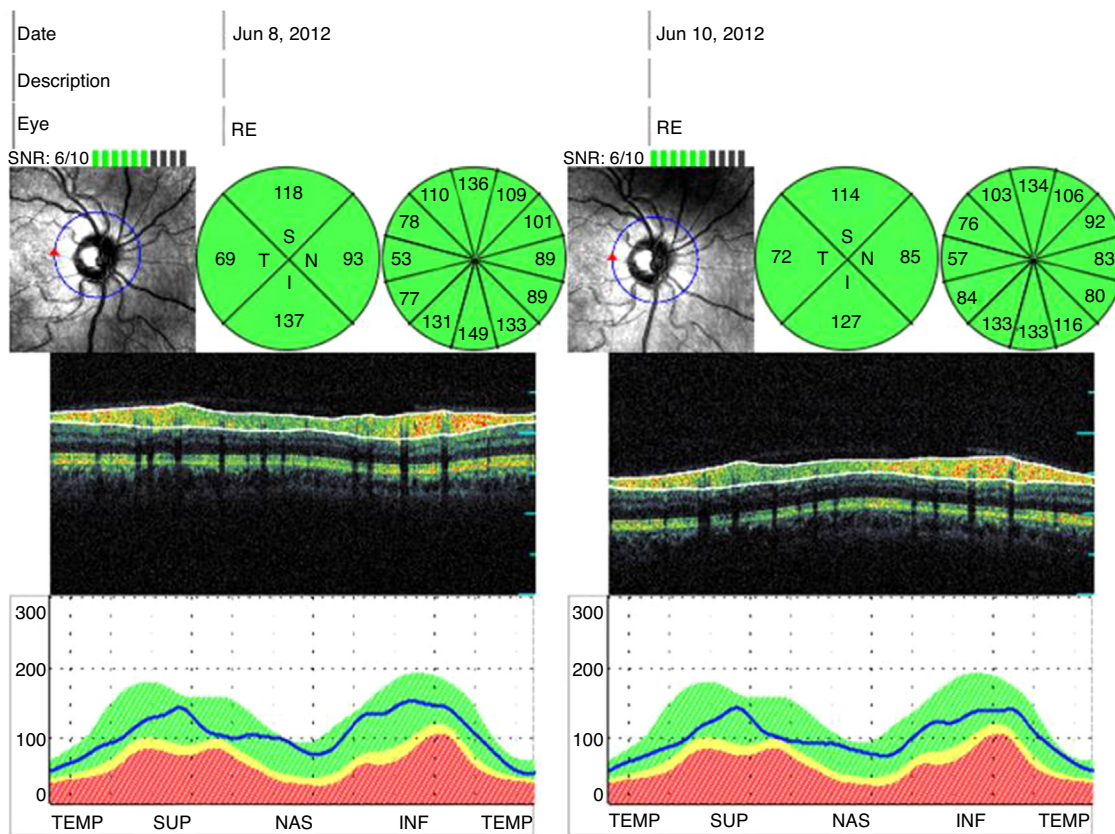


Figure 1 The comparison of the retinal nerve fiber layer thickness measurements obtained by spectral domain, one day before and after the operation.

Power analysis

The main focus of our study was to determine postoperative RNFLT. The sampling size was determined following a study by Hong et al.,¹⁹ where inferior quadrant RNFLT average was reported as $139.9 \pm 11.8 \mu\text{m}$. The patient number required to determine an average reduction in inferior quadrant RNFLT (with 5% of normal values, 0.05α error and 80% power) was calculated as 30. The sample size was determined by a power calculator.

Statistical analyses

Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS), version 15.0, for Windows (SPSS, Chicago, IL). The Shapiro–Wilk normality test was used to examine the compatibility between the measured variables and the normal distribution. The Wilcoxon test was used to compare pre- and postoperative RNFLT measurements. During the operation the changes in IOP and hemodynamic parameters measured at six different times were later evaluated using the Friedman test. Pairwise comparisons were performed using the Wilcoxon and Mann–Whitney *U* test. The relationship between RNFLT changes and parameters showing significant changes during the operation were examined using the Spearman correlation test. The data were shown as median (minimum–maximum), and the level of significance was accepted as $p < 0.05$.

Results

A total of 32 patients underwent spinal surgeries between May and November 2012. Among them, 30 patients were included in our study, while two patients were excluded due to tilted disk. There were 10 male and 20 female patients, with an average age of 54.9 ± 13.4 years. The patient characteristics and properties relating to the operation are summarized in Table 1.

Preoperative and postoperative median values of superior, temporal, inferior and nasal quadrant RNFLT measurements are given in Table 2. There was no significant difference between postoperative and preoperative measurements for superior and temporal quadrants ($p > 0.05$). However, a statistically significant thinning was observed in inferior ($p = 0.009$) and nasal quadrants ($p = 0.003$) (Table 2).

The patients' IOP and hemodynamic measurements are summarized in Table 3. When compared to the baseline, a reduction in IOP was seen at Supine 1 ($p < 0.001$).

Table 1 Patient variables.

| Variable | Data |
|--------------------------|----------------|
| Age (years) | 57 (28–80) |
| Gender (male/female) | 10/20 |
| BMI (kg/m ²) | 28.3 (18.7–45) |
| Anesthesia time (min) | 140 (82–260) |
| Prone time (min) | 130 (70–255) |
| Operation time (min) | 120 (60–242) |
| Blood loss (mL) | 350 (100–1200) |
| Colloid infusion (mL) | 400 (0–1200) |

Variables are shown as the median (range).

BMI, Body mass index; min, minutes; mL, millilitres

A statistically significant IOP elevation was observed in Prone 2 ($p < 0.001$) and Prone 3 ($p = 0.01$) when compared to baseline values. Hemodynamic changes showed that SBP, DBP and MAP were significantly lower at Prone 1 ($p = 0.02$, $p = 0.03$, $p = 0.01$), Prone 2 ($p < 0.001$ for all) and Prone 3 ($p = 0.001$ for all) when compared to baseline. Average OPP values were significantly lower than baseline at Prone 1 ($p = 0.01$), Prone 2 ($p < 0.001$) and Prone 3 ($p = 0.004$). Heart rates were significantly lower at Prone 2 ($p = 0.01$) and Prone 3 ($p = 0.01$) when compared to baseline. At all times, SpO₂ values were significantly higher when compared to baseline (Supine 1 and Prone 2; $p < 0.001$, Prone 1 and Supine 2; $p = 0.001$, Prone 3; $p = 0.005$). Calculated liquid balance for all patients was positive, and average values were 1325 (550–3000) mL. Preoperative and postoperative average Hb values were 13.2 (11–16.3) g/dL and 11.1 (8.1–14.1) g/dL, respectively; while Htc values were 39.3 (33.8–48.7) g/dL and 34.2 (25–43.1) g/dL. The reductions in postoperative Hb and Htc values were statistically significant ($p < 0.001$ for both).

No significant correlation was found between the amount of RNFLT thinning and patients age, BMI, anesthesia duration, blood loss, and administered colloid amount, changes of IOP and OPP during the operation ($p > 0.05$) (Table 4).

Discussion

This prospective study aimed to examine changes in RNFLT and factors affecting those changes in patients who underwent spinal surgery in the prone position. When we evaluated the changes in RNFLT measured by SD-OCT, we observed a thinning in the inferior and nasal quadrants on the first postoperative day compared to preoperative

Table 2 Preoperative and postoperative measurements of retinal nerve fiber layer thickness at four quadrants.

| RNFLT | Superior (μm) | Temporal (μm) | Inferior (μm) | Nasal (μm) |
|---------------|----------------------------|----------------------------|-----------------------------|--------------------------|
| Preoperative | 115 (98–149) | 66.5 (46–96) | 129 (91–158) | 78.5 (55–119) |
| Postoperative | 115.5 (81–156) | 69.5 (47–105) | 126.5 (87–164) ^a | 72 (59–101) ^a |
| <i>p</i> | NS | NS | 0.009 | 0.003 |

Variables are shown as the median (range).

RNFLT, retinal nerve fiber layer thickness; μm , micrometer; NS, non significant.

^a $p < 0.05$, compared with preoperative RNFLT, Wilcoxon signed ranks test.

Table 3 Intraocular pressure, blood pressure (systolic, diastolic, mean), ocular perfusion pressure and heart rate measurements during operation.

| | IOP (mmHg) | SBP (mmHg) | DBP (mmHg) | MAP (mmHg) | OPP (mmHg) | HR (beats/min) |
|---------------------------|-------------------------|-----------------------------|-------------------------|----------------------------|---------------------------|---------------------------|
| Baseline (<i>n</i> = 30) | 15 (7–20) | 130 (91–202) | 77 (60–111) | 95 (69–149) | 79.5 (53–134) | 75 (55–100) |
| Supine 1 (<i>n</i> = 30) | 10 (5–24) ^a | 120 (86–190) | 75 (54–112) | 86 (63–133) | 75.5 (47–119) | 78.5 (55–100) |
| Prone 1 (<i>n</i> = 30) | 14.5 (6–31) | 117 (78–156) ^a | 76 (44–99) ^a | 92 (54–122) ^a | 71 (38–109) ^a | 76 (57–109) |
| Prone 2 (<i>n</i> = 30) | 19 (10–37) ^a | 107.5 (81–148) ^a | 71 (53–94) ^a | 82 (68–104) ^a | 62.5 (35–92) ^a | 69.5 (54–93) ^a |
| Prone 3 (<i>n</i> = 18) | 15 (11–35) ^a | 109 (90–132) ^a | 70 (58–85) ^a | 81.5 (72–105) ^a | 64 (46–90) ^a | 69 (62–98) ^a |
| Supine 2 (<i>n</i> = 30) | 15.5 (9–32) | 128 (81–170) | 77.5 (62–99) | 98 (70–127) | 80 (46–115) | 78.5 (55–99) |

Variables are shown as the median (range).

IOP, intraocular pressure; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; OPP, ocular perfusion pressure; HR, heart rate.

^a *p* < 0.05, compared with baseline value, Wilcoxon signed ranks test.

measurements. We observed a significant increase in IOP in the prone position while there was a significant decrease in hemodynamic factors. However, we did not find any correlation between the changing of all parameters during the operation and the RNFLT thinning.

POVL, occurring after spinal surgery in the prone position is a serious complication which has been linked, in order of decreasing frequency, to posterior ION, anterior ION and central artery occlusion, but its etiology is still not well understood.^{1–3,6} It has been proposed that IOP elevation in the prone position reduces ocular perfusion, especially in cases whose MAP remains stable, thereby causing anterior ION or central retinal arterial occlusion.¹²

The first study investigating IOP changes in spinal surgery in the prone position was carried out by Cheng et al.¹⁰ They observed a significant IOP elevation at the beginning (27 ± 2 mmHg) and at the end (40 ± 2 mmHg) of the operation in the prone position when compared with baseline values (19 ± 1 mmHg) measured in the supine position. However, they did not investigate intraoperative IOP changes. In another study evaluating patients who underwent spinal surgery, it was found that the average IOP values in the supine position after anesthesia induction were 11.5 mmHg, while in the prone position at the beginning and at the end of surgery IOP values were 23.5 mmHg and 30.5 mmHg, respectively.¹⁰ They determined that in the prone position, these values were significantly higher than in the supine

position. In various studies using healthy volunteers, IOP values in the prone position were found to be significantly higher than in the sitting position.^{20,21}

To the best of our knowledge, this study is the most comprehensive study till date investigating IOP changes in the prone position. IOP was measured in the prone position at the 10th, 60th and 120th minutes of operation. We found that IOP was highest at the 60th minute, and it reduced slightly at the 120th minute, which was still significantly higher than baseline values. While our study on IOP changes during the operation has a variation curve similar to other studies, any differences may be linked to erroneous high measurements due to excessive eyelid opening or pressure on the globe.

Spectral domain OCT provides reliable and repeatable measures of the nerve fiber layer of the optic nerve at the level of 7–15 μ m.²² These properties have led it to becoming the most important diagnostic tool for early diagnosis and follow-up for disorders involving the front part of the visual pathway.²³ In a previous study, interoperator (intraclass correlation coefficient (ICC), 0.87; CV, 2.89%) and intraoperator (ICC, 0.94 and 0.95; CV, 1.28% and 1.26%, respectively, for operator A and operator B) agreement have been found for average RNFLT measurements using OTI Spectral OCT/SLO.²⁴

This study is the first in the literature to evaluate RNFLT changes following spinal surgery in the prone position. On the first postoperative day, a significant thinning was

Table 4 The correlations between inferior and nasal quadrants' retinal nerve fiber layer thickness changes and patients variables.

| Variables (<i>n</i> = 30) | Inferior quadrant change | | Nasal quadrant change | |
|---------------------------------|--------------------------|-----------------------|-----------------------|-----------------------|
| | <i>r</i> ^a | <i>p</i> ^a | <i>r</i> ^a | <i>p</i> ^a |
| Age | –0.13 | 0.50 | 0.05 | 0.80 |
| BMI | –0.02 | 0.90 | 0.05 | 0.81 |
| Anesthesia duration | 0.22 | 0.24 | 0.33 | 0.07 |
| Blood loss | 0.07 | 0.70 | 0.29 | 0.11 |
| Colloid infusion | –0.09 | 0.64 | 0.29 | 0.12 |
| IOP change (Prone 2 – baseline) | 0.25 | 0.18 | 0.16 | 0.41 |
| OPP change (Prone 2 – baseline) | –0.14 | 0.45 | –0.35 | 0.85 |

^a Spearman's rank correlation.

BMI, body mass index; IOP, intraocular pressure; OPP, ocular perfusion pressure.

observed in the inferior and nasal quadrants. While there was a significant rise in IOP in the prone position, there was a significant decrease in hemodynamic factors. However, no significant correlation was found between patients' age, BMI, anesthesia duration, blood loss or given colloids, IOP or OPP changes and thinning in RNFL. Similarly, Fortune et al.¹⁶ showed that acute IOP increase caused RNFL thinning in rat eyes, and this thinning returned to normal values after a month. Piette et al.¹⁴ found that acute IOP increase caused by suction in LASIK patients, which resulted in a statistically significant thinning of RNFL, and even after IOP values returned to normal this thinning remained. In another study, all GDx parameters except for symmetry showed statistically significant reduction on the first postoperative day in patients who underwent coronary artery bypass operation. By the 5th postoperative day, superior/nasal ratio parameters returned to normal values, however, by the first postoperative month the inferior ratio values were still under normal values.²⁵ This study supports our results showing that the inferior quadrant retinal nerve fibers are more sensitive.

Although the number of patients in our study is comparable to similar studies, low patient number is the most important limitation. Another limitation was the lack of long-term follow-ups. The progress of RNFL changes was not evaluated in this study.

In conclusion, spinal surgical interventions in the prone position lead a significant inferior and nasal quadrants thinning in RNFL at the early postoperative period even though patients do not suffer from vision loss. But there was not found any significant correlation between the amount of RNFL thinning and changes of IOP during the operation in this study. Larger controlled studies with longer follow-up will be required to fully determine the role of prone position on RNFL changes.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Patil CG, Lad EM, Lad SP, et al. Visual loss after spine surgery: a population-based study. *Spine*. 2008;33:1491–6.
2. Stevens WR, Glazer PA, Kelley SD, et al. Ophthalmic complications after spinal surgery. *Spine*. 1997;22:1319–24.
3. Chang SH, Miller NR. The incidence of vision loss due to perioperative ischemic optic neuropathy associated with spine surgery: the Johns Hopkins Hospital Experience. *Spine*. 2005;30:1299–302.
4. Alexandrakis G, Lam BL. Bilateral posterior ischemic optic neuropathy after spinal surgery. *Am J Ophthalmol*. 1999;127:354–5.
5. Ho VT, Newman NJ, Song S, et al. Ischemic optic neuropathy following spine surgery. *J Neurosurg Anesthesiol*. 2005;17:38–44.
6. Lee LA, Roth S, Posner KL, et al. The American Society of Anesthesiologists Postoperative Visual Loss Registry: analysis of 93 spine surgery cases with postoperative visual loss. *Anesthesiology*. 2006;105:652–9.
7. The Postoperative Visual Loss Study Group. Risk factors associated with ischemic optic neuropathy after spinal fusion surgery. *Anesthesiology*. 2012;116:15–24.
8. Hayreh SS. Ischemic optic neuropathy. *Prog Retin Eye Res*. 2009;28:34–62.
9. Ozcan MS, Praetel C, Bhatti MT, et al. The effect of body inclination during prone positioning on intraocular pressure in awake volunteers: a comparison of two operating tables. *Anesth Analg*. 2004;99:1152–8.
10. Cheng MA, Todorov A, Tempelhoff R, et al. The effect of prone positioning on intraocular pressure in anesthetized patients. *Anesthesiology*. 2001;95:1351–5.
11. Hunt K, Bajekal R, Calder I, et al. Changes in intraocular pressure in anesthetized prone patients. *J Neurosurg Anesthesiol*. 2004;16:287–90.
12. Roth S. Perioperative visual loss: what do we know, what can we do? *Br J Anaesth*. 2009;103:31–40.
13. Sugata A, Hayashi H, Kawaguchi M, et al. Changes in intraocular pressure during prone spine surgery under propofol and sevoflurane anesthesia. *J Neurosurg Anesthesiol*. 2012;24:152–6.
14. Piette S, Liebmann JM, Ishikawa H, et al. Acute conformational changes in the optic nerve head with rapid intraocular pressure elevation: implications for LASIK surgery. *Ophthalm Surg Lasers Imaging*. 2003;34:334–41.
15. Fortune B, Yang H, Strouthidis NG, et al. The effect of acute intraocular pressure elevation on peripapillary retinal thickness, retinal nerve fiber layer thickness, and retardance. *Invest Ophthalmol Vis Sci*. 2009;50:4719–26.
16. Fortune B, Choe TE, Reynaud J, et al. Deformation of the rodent optic nerve head and peripapillary structures during acute intraocular pressure elevation. *Invest Ophthalmol Vis Sci*. 2011;52:6651–61.
17. Contreras I, Rebolleda G, Noval S, et al. Optic disc evaluation by optical coherence tomography in nonarteritic anterior ischemic optic neuropathy. *Invest Ophthalmol Vis Sci*. 2007;48:4087–92.
18. Hoff JM, Varhaug P, Midelfart A, et al. Acute visual loss after spinal surgery. *Acta Ophthalmol*. 2010;88:490–2.
19. Hong JT, Sung KR, Cho JW, et al. Retinal nerve fiber layer measurement variability with spectral domain optical coherence tomography. *Korean J Ophthalmol*. 2012;26:32–8.
20. Lam AK, Douthwaite WA. Does the change of anterior chamber depth or/and episcleral venous pressure cause intraocular pressure change in postural variation? *Optom Vis Sci*. 1997;74:664–7.
21. Walick KS, Kragh Jr JE, Ward JA, et al. Changes in intraocular pressure due to surgical positioning: studying potential risk for postoperative vision loss. *Spine*. 2007;32:2591–5.
22. Aref AA, Budenz DL. Spectral domain optical coherence tomography in the diagnosis and management of glaucoma. *Ophthalm Surg Lasers Imaging*. 2010;41:15–27.
23. Savini G, Carbonelli M, Barboni P. Spectral-domain optical coherence tomography for the diagnosis and follow-up of glaucoma. *Curr Opin Ophthalmol*. 2011;22:115–23.
24. Pierro L, Gagliardi M, Iuliano L, et al. Retinal nerve fiber layer thickness reproducibility using seven different OCT instruments. *Invest Ophthalmol Vis Sci*. 2012;53:5912–20.
25. Buyukates M, Kargi S, Kandemir O, et al. The use of the retinal nerve fiber layer thickness measurement in determining the effects of cardiopulmonary bypass procedures on the optic nerve. *Perfusion*. 2007;22:401–6.