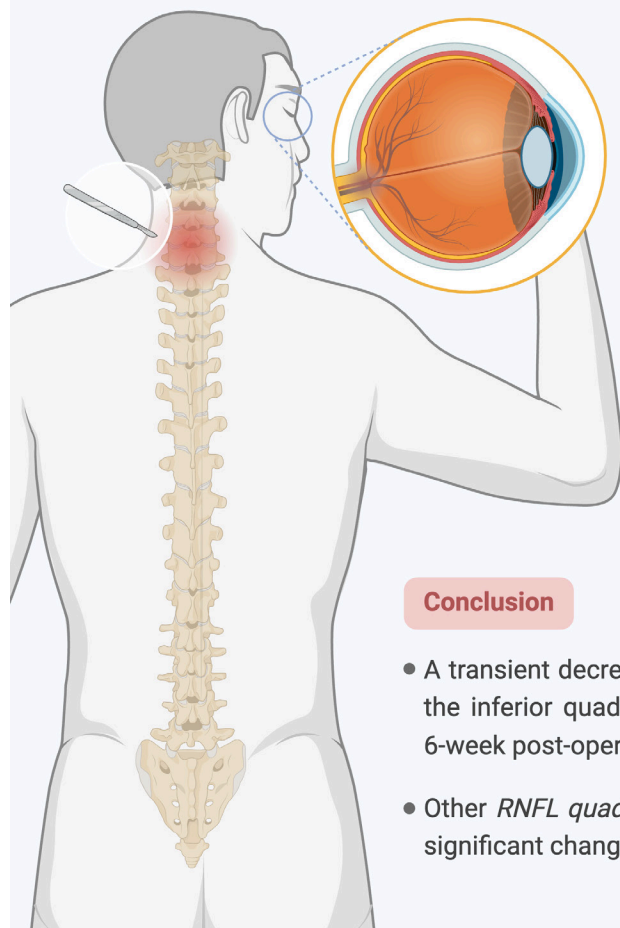


Changes in Retinal Nerve Fiber Layer and Macular Ganglion Cell-Inner Plexiform Layer Thickness after Spinal Surgery in the Prone Position

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The prone position during spinal surgery may be a factor associated with the development of posterior ischemic optic neuropathy



N=38

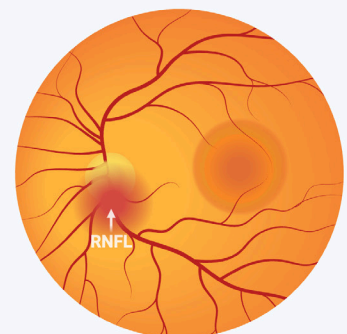
19 patients undergoing spinal surgery (38 eyes)



The RNFL and GCIPL thickness were evaluated by optical coherence tomography before and after surgery (6-week, 3-month)

Conclusion

- A transient decrease in RNFL thickness in the inferior quadrant was observed at the 6-week post-operative.
- Other RNFL quadrants and GCIPL were no significant changes.



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T Deeprasertwit et al. *Siriraj Med J* 2024;76(10):689-95.

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Received 25 April 2024 Revised 26 July 2024 Accepted 30 July 2024

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<https://doi.org/10.33192/smj.v76i10.268907>



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ABSTRACT

Objective: Postoperative visual loss resulting from posterior ischemic optic neuropathy (PION) after spinal surgery is rare but devastating. A potential risk factor is prolonged spinal surgery in the prone position. We hypothesized that if this risk factor is linked to PION, the retinal nerve fiber layer (RNFL) and macular ganglion cell-inner plexiform layer (GCIPL) should decrease post-surgery.

Materials and Methods: The prospective cohort study was conducted in patients undergoing spinal surgery in the prone position. The RNFL and GCIPL thickness by optical coherence tomography before and after spinal surgery (6-week, 3-month post-operative) were analyzed.

Results: Nineteen patients (38 eyes) completed the study with three follow-up timepoints. The mean age was 53.78 $\pm$ 12.71 years. No significant changes were observed in the RNFL thickness and macular ganglion cell-inner plexiform layer changes at the 6 weeks and 3 months follow-ups, except for the RNFL at the inferior quadrant at 6 weeks follow-up. There were also no patients who experienced visual loss.

Conclusion: A transient decrease in RNFL thickness in the inferior quadrant was observed at the 6-week post-operative follow-up after spinal surgery. The prone position during surgery may be an intraoperative factor associated with the development of perioperative PION in patients undergoing spinal procedures.

Keywords: Retinal nerve fiber layer; macular ganglion cell-inner plexiform layer; spinal surgery; prone position; posterior ischemic optic neuropathy (Siriraj Med J 2024; 76: 689-695)

INTRODUCTION

Postoperative visual loss following non-ocular surgeries has been documented since 1982.¹⁻³ This complication has been reported in various procedures, including coronary artery bypass graft⁴, open heart surgery⁵, radical neck dissection⁶, liver transplantation⁷, and spinal surgery.^{2,8} A decade-long (1996-2005) retrospective analysis of data from the Nationwide Inpatient Sample in the US identified spinal fusion, cardiac, and non-spinal orthopedic surgeries as having the highest incidences of postoperative visual loss,² with a prevalence of 8.64 cases per 10,000 in cardiac surgery and 3.09 cases per 10,000 in spinal fusion.² The most commonly associated conditions with postoperative visual loss include posterior ischemic optic neuropathies (PION), cortical blindness, and retinal vascular occlusion.² Although postoperative visual loss after non-ocular surgeries is rare, it can lead to devastating complications.

The etiology of perioperative PION remains elusive. Previous reports have identified several potential contributing factors, including prolonged surgeries in the prone position, decreased ocular perfusion pressure, hemodilution or anemia, blood loss, intraoperative hypotension, and the administration of large volumes of intravenous fluids.^{2,11}

Previous research has shown a decrease in the thickness of the retinal nerve fiber layer (RNFL) six weeks after incidents of postoperative PION.¹² To investigate the possible relationship between these risk factors and perioperative PION, our study hypothesizes that even

patients who do not experience significant postoperative visual loss may still exhibit a reduction in RNFL and macular ganglion cell-inner plexiform layer (GCIPL) thickness post-surgery. The measurement of RNFL and GCIPL thickness can be done accurately using Optical Coherence Tomography (OCT), a widely used non-invasive tool to diagnose various optic nerve diseases.¹²

To explore these factors, including the role of prolonged surgeries in the prone position, we chose spinal surgery as our context. This surgery is increasingly common, leading to a surge in research aimed at enhancing patient safety. One notable area of research involves using AI to predict preoperative and postoperative venous thromboembolism in patients undergoing surgery for spinal metastasis.¹³ Additionally, there are studies focused on survival analysis and identifying prognostic factors for metastatic epidural spinal cord compression, comparing cases with preoperatively known and unknown primary tumors.¹⁴ However, there remains a scarcity of clinical studies on perioperative Posterior Ischemic Optic Neuropathy (PION), and most of our knowledge is derived from isolated case reports or retrospective reviews. We designed this study as a prospective investigation to provide a more comprehensive understanding of PION following surgery. We also collected intraoperative data to identify potential factors associated with perioperative PION. This study focuses on analyzing RNFL and GCIPL thickness using OCT in patients both before and after spinal surgery.

MATERIALS AND METHODS

Patients and data collection

This study was structured as a prospective cohort investigation. We enrolled patients diagnosed with spinal conditions who were scheduled for spinal surgery at Siriraj Hospital from November 2013 to June 2015 following prior approval from the Siriraj Institutional Review Board. All patients provided written informed consent, and the study adhered to principles of the Declaration of Helsinki. The inclusion criteria specified that patients be 18 or older, with no pre-existing ocular diseases or conditions impacting the optic nerve. We also ensured that candidates did not have ocular or systemic conditions known to affect RNFL thickness, such as diabetes mellitus, glaucoma, age-related macular degeneration, optic neuropathy, or a history of ocular surgery or trauma. We excluded patients with other optic nerve disorders, including ischemic optic neuropathy, glaucoma, neuroretinitis, perineuritis, and optic neuropathy related to central nervous system infections, toxicity, or malignancy. Patients with macular diseases or those with pathologic myopia (spherical equivalent refractive error >6.0 diopters) were also excluded. Participants who had disabilities precluding examination or were at risk of loss to follow-up were excluded as well.

After obtaining informed consent, we gathered patient data, including age, spinal disease diagnosis, planned surgery type, medical history, and current medication regimen. A comprehensive ophthalmic examination was conducted for each patient, which included Best Corrected Visual Acuity (BCVA), non-contact tonometry, slit lamp examination, funduscopy, color vision assessment, and evaluation for relative afferent pupillary defects. Retinal nerve fiber layer (RNFL) and macular ganglion cell-inner plexiform layer (GCIPL) thickness measurements were obtained using the Cirrus SD-OCT from the Cirrus HD-OCT 5000 system (Software Version: 6.0.0.599, Carl Zeiss Meditec). We applied the optic disc cube (200x200) and macular cube (512x128) scan protocols. These ophthalmic evaluations were performed on both eyes of each participant the day before surgery and were repeated during two post-operative follow-up visits scheduled for 6 weeks and 3 months. The follow-up appointments were synchronized with the orthopedic clinic's schedule for postoperative care. The RNFL and GCIPL thickness were measured in microns and segmented into average, superior, temporal, nasal, and inferior quadrants of the optic disc for each eye. Additionally, we meticulously recorded intraoperative data, which included the patient's position, episodes of hypotension, blood loss, and duration of operative procedure.

Data analysis

Statistical analysis was performed using means and standard deviations (SD) for continuous variables, and medians (min, max) for categorical data. RNFL and GCIPL thickness measurements, taken before and after surgery for each eye, were analyzed using linear mixed models. Furthermore, multivariate analysis of these models was employed to assess the relationship between intraoperative factors and changes in thickness.

RESULTS

Our study, designed as a pilot investigation studying the effects of spinal surgery, initially recruited a total of 60 patients. However, due to the high attrition rate during the data collection phase, two-thirds of the patients failed to follow-up. Ultimately, 19 patients (equal to 38 eyes) completed all three rounds of follow-up assessments. The participant pool was fairly gender-balanced, with ten males and nine females. The average age of the study population was 53.78 $\pm$ 12.71 years. Most patients (63.2%) had no prior medical or ocular comorbidities (Table 1).

The mean preoperative BCVA, measured in logmar, was 0.1061 (SD: 0.10407). At the three-month post operative mark, the mean BCVA logmar was 0.1178 (SD: 0.09081). There was no statistically significant difference observed between preoperative and postoperative BCVA logmar values.

The most common spinal conditions among participants in this study were cervical spondylomyelopathy, affecting 6 out of 19 patients (31.6%), and ossification of the posterior longitudinal ligament, seen in 5 out of 19 patients (26.3%). All 19 patients underwent surgery in the prone position, with thirteen experiencing intraoperative hypotension. The mean operative time was 215.88 minutes, with a median time of 180 minutes (range: 95 to 385 minutes). The average intraoperative blood loss was 997.78 milliliters, with a median loss of 250 milliliters, (range: 20 to 4200 milliliters) (Table 2).

OCT analysis yielded results that showed no statistically significant changes in RNFL thickness, both in the overall average measurement and across all quadrants, at the 6-week and 3-month post-operative follow-up points. However, a notable decrease was observed in the inferior quadrant of the RNFL at the 6-week follow-up, when compared to pre-surgical RNFL measurements. Nevertheless, at the 3-month follow-up, RNFL thickness in the inferior quadrant showed no significant thinning compared to the preoperative baseline (Table 3). Similarly, GCIPL thickness measurements, both the average measurement and quadrant-specific data, also revealed no statistically significant changes at the 6-week and 3-month follow-up

TABLE 1. Demographic data of patients.

Demographic data of patients		
Age (mean±SD)		53.78±12.71
Gender: n (%)		
Male		10 (52.6%)
Female		9 (47.4%)
Medical history: n (%)		
None		12 (63.2%)
Hypertension and dyslipidemia		4 (21.1%)
Diabetes mellitus		3 (15.8%)

Abbreviation: SD: standard deviation

TABLE 2. Demographic data of operations.

Demographic data of operations		
Spinal disease: n (%)		
Cervical spondylosis myelopathy		6 (31.6%)
Ossification of the posterior longitudinal ligament		5 (26.3%)
Spinal stenosis		3 (15.8%)
Herniated nucleus pulposus		3 (15.8%)
Spondylolisthesis		2 (10.5%)
Operative Time (minute)		
Mean ± SD		215.88 ± 85.041
Median (min-max)		180 (95-385)
Hypotension: n (%)		
No		6 (31.6%)
Yes		13 (68.4%)
Blood loss (ml.)		
Mean ± SD		997.78 ± 1365.924
Median (min-max)		250 (20-4200)

Abbreviation: SD: standard deviation.

TABLE 3. Thickness of retinal nerve fiber layer and macular ganglion cell-inner plexiform layer in each quadrant, preoperative and postoperative, at 6 weeks and 3 months.

	Time			p-value	
	Preoperative	6 weeks Post-operative	3 months Post-operative	Pre and post 6 weeks	Pre and post 3 months
RNFL, Mean (SD)					
Average	96.11 (8.71)	94.59 (8.79)	94.83 (9.28)	0.247	0.092
Superior	119.74 (13.65)	120.65 (13.22)	118.36 (13.10)	0.065	0.362
Nasal	73.26 (8.44)	72.38 (10.04)	72.22 (10.07)	0.674	0.518
Inferior	123.74 (15.40)	119.62 (16.18)	122.44 (16.31)	0.030	0.681
Temporal	67.63 (11.79)	67.21 (12.09)	67.47 (12.20)	0.994	0.547
GCIPL, Mean (SD)					
Average	79.42 (11.17)	78.35 (11.32)	79.36 (10.35)	0.524	0.460
Superior	80.19 (12.43)	79.35 (12.00)	80.39 (9.88)	0.864	0.887
Inferior	76.69 (14.20)	75.41 (14.09)	76.64 (14.88)	0.449	0.379
Supero-nasal	81.39 (13.91)	81.03 (12.48)	82.36 (9.82)	0.787	0.451
Infero-nasal	79.31 (13.23)	78.68 (12.89)	79.11 (13.37)	0.867	0.282
Infero-temporal	80.31 (8.25)	79.24 (7.16)	79.00 (11.18)	0.771	0.109
Supero-temporal	78.78 (9.01)	78.09 (7.96)	79.06 (9.70)	0.909	0.905

Abbreviations: SD: standard deviation, Significant differences are shown in bold ($p < 0.05$).

RNFL: retinal nerve fiber layer, GCIPL: macular ganglion cell-inner plexiform layer.

assessments. At the end of the follow-up period, none of the study patients experienced any form of visual loss or developed new ocular conditions.

DISCUSSION

Perioperative PION is an exceptionally rare condition characterized by an elusive etiology. It is characterized by the sudden, and painless onset of severe visual impairment, with an initially normal optic disc appearance, following non-ocular surgical procedures.¹⁵ It typically presents as bilateral visual loss, though unilateral cases have also been documented.^{15,16} The most severe cases may result in visual acuity reduced to mere finger counting or even a complete loss of light perception.^{17,18} This condition predominantly affects middle-aged and otherwise healthy individuals.

The causation of perioperative PION is likely multifactorial, with potential risk factors including hemodilution, anemia, hypotension resulting from significant blood loss, and extended surgical durations.¹⁵ Spinal surgeries conducted with the patient in the prone position have a particular association with perioperative

PION. The hypothesis is that venous engorgement during surgery could increase pressure within the optic nerve, and thus contribute to its occurrence. This theory is supported by the observation of increased intraocular pressure when individuals, whether awake or anesthetized state, are placed in the prone position.¹⁹ Additionally, the posterior optic nerve's blood supply, particularly in its watershed area, is thought to be especially vulnerable to elevated venous pressure due to its reliance on small end vessels.^{15,20,21}

None of the participants in this study experienced postoperative visual loss throughout the entire follow-up period. Furthermore, no statistically significant changes were detected in RNFL thickness, both overall and across all quadrants, at the 6-week and 3-month post-operative time points. However, a specific reduction in RNFL thickness was noted in the inferior quadrant at the 6-week follow-up mark compared to the preoperative RNFL measurements. Remarkably, this reduction in the inferior quadrant was not present at the 3-month follow-up, indicating a return to baseline levels (refer to [Table 3](#)). Similarly, GCIPL thickness measurements, both

overall average and by quadrants, showed no statistically significant changes at the 6-week and 3-month post-operative assessments.

It is essential to note that a recent prospective study reported significant RNFL thinning in the nasal and inferior regions just one day after spinal surgery in patients who underwent surgery in the prone position.¹⁹ This discrepancy may be explained by the temporary nature of the thinning observed in the inferior quadrant at 6 weeks in this study, possibly due to a mild degree of ischemia that subsequently resolved. It is important to recognize that the sample size of this study might be too small to conclusively determine this effect. Furthermore, while postoperative ION can occur due to various factors, including severe and prolonged hypotension, anemia, and hemodilution, these conditions may not have been severe enough in this study to significantly impact the RNFL and GCIPL.

In this study, no direct link was found between episodes of hypotension and changes in RNFL and GCIPL thickness. The factors contributing to the onset of perioperative PION, specifically hypotension and anemia, remain unclear, as PION can develop in patients even without these risk factors. Furthermore, it is challenging to establish a direct relationship between surgery duration, volume of blood loss, and the incidence of perioperative PION.

A limitation of this study is the relatively small sample size, which constrains the precision of the results. Future research should aim to recruit a larger pool of participants, control for variables such as examiner bias, and ensure consistent follow-up timing to achieve more accurate and significant results, particularly assessment of RNFL thickness in the inferior quadrant.

CONCLUSION

The data indicates a trend toward reduced RNFL thickness in the inferior region of the optic disc relative to preoperative measurements. This suggests the prone position during surgery may be an intraoperative factor linked to the development of perioperative PION.

ACKNOWLEDGEMENTS

The authors are also indebted to Aditya Rana for English-language editing of this paper. Finally, the authors thank the study participants who made the research possible.

Financial support

None

Conflict of interest

There are no conflicts of interest to declare.

Author contribution statement

Conceptualization, TD; methodology, PB and NC; software, DS; validation, SW, AE, TD and DS; formal analysis, NC and YM; investigation, PB; resources, SW; data curation, AE and YM; writing—original draft, TD; writing—review and editing, NP; visualization, DS; supervision, NC and SW; project administration, TD and, AE; Selection of patients, SW. All authors read and agreed to the published version of the manuscript.

Data availability statement

The datasets generated and analyzed during the study are available from the corresponding author upon reasonable request.

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