J Anesth (2015) 29:170–174
DOI 10.1007/s00540-014-1921-8

ORIGINAL ARTICLE

Evaluation of predictive factors associated with increased intraocular pressure during prone position spine surgery

Kie Yoshimura · Hironobu Hayashi · Yuu Tanaka · Yasumitsu Nomura · Masahiko Kawaguchi

Received: 26 May 2014 / Accepted: 7 September 2014 / Published online: 24 September 2014

Abstract
Background Intraocular pressure(IOP) has been shown to increase during prone position spine surgery. The present study was conducted to evaluate IOP changes and predictive factors associated with increased IOP during prone position spine surgery.
Methods After institutional approval and written informed consent, 56 patients undergoing prone position spine surgery were studied. Anesthesia was maintained with propofol or sevoflurane, remifentanil, and fentanyl. IOP was measured using a Tono-Pen XL hand-held tonometer 10 min after induction of anesthesia, every 60 min after prone positioning, and 10 min after returning to the supine position. According to maximum IOP, patients were divided into group H with a maximum IOP value of ≥30 mmHg or group L with a maximum IOP value of <30 mmHg. Logistic regression analyses were performed to identify predictive factors associated with increased IOP.
Results Maximum IOP values ranged from 19–40 mmHg and 20 patients were included in group H. There were no statistically significant differences in demographic and intraoperative variables between the two groups. IOP 1 h after prone positioning (IOP1H) was significantly higher in group H than in group L. Logistic regression analysis revealed that IOP1H of ≥23 mmHg was a significant predictor (odds ratio 19.0, 95 % C.I 3.7–97.6).
Conclusion IOP1H values may be used as a predictive factor associated with increased IOP during prone position spine surgery.

Keywords Intraocular pressure · Spine surgery · Prone position · Anesthesia

K. Yoshimura · H. Hayashi · Y. Tanaka · Y. Nomura · M. Kawaguchi (✉)
Department of Anesthesiology, Nara Medical University, 840 Shijo-cho, Kashihara, Nara 634-8522, Japan
e-mail: drjkawa@naramed-u.ac.jp

Introduction

Intraocular pressure (IOP) has been shown to increase during prone position spine surgery [1, 2]. Recent evidence indicated that increased IOP was not associated with posterior ischemic optic neuropathy, which is considered to be the most prevalent cause of postoperative visual loss after prone position spine surgery [2, 3]. However, increased IOP may contribute to the development of other ophthalmological complications including central retinal artery occlusion, retinal ischemic injury and deterioration of glaucoma. Riva et al. [4, 5] reported that autoregulation of retinal blood flow remained normal under conditions of acutely increased IOP up to approximately 30 mmHg in human eyes. Pillunat et al. [6] reported that blood flow to the optic nerve remained nearly constant until ocular pressures reached 40 mmHg in adult volunteers. Although the value at which the IOP significantly influences retinal blood flow is still controversial, the information suggests that 30 mmHg may be the lowest end of the range for possible harm.

Recent advances in technology allow us to measure IOP intraoperatively. Several investigators have reported the results of intraoperative recordings of IOP using a Tono-Pen portable hand-held tonometer [7, 8]. However, intermittent repetitive recording of IOP during prone position spine surgery using this device may not be practical due to

the limited space for measurements and the possibility of interrupting the surgical procedure. Therefore, any measures to predict intraoperative IOP changes may be of clinical value. As an ophthalmological examination, prone IOP tests may be used to assess IOP changes in patients with or without glaucoma, in which IOP is measured within 1 h after prone positioning [9]. In glaucoma patients, IOP increases may be marked compared with non-glaucoma patients. In the present study, we hypothesized that IOP measurement 1 h after prone positioning may be used as a predictor of intraoperative IOP increase during prone position spine surgery. Early prediction of an increase in IOP may provide an opportunity to manage subsequent IOP changes. The present study was therefore conducted to investigate changes in IOP values and the predictive factors associated with increased IOP during prone position spine surgery.

Materials and methods

After institutional approval at Nara Medical University, Nara, Japan, written informed consent was obtained from all 56 patients aged >18 years. Patients who had glaucoma and ophthalmic disease other than myopia or hypermetropia were excluded. The study was conducted in compliance with the Declaration of Helsinki. The data in this study was extracted from the trial, which was registered in the University Hospital Medical Information Network (UMIN000 002875). Induction of anesthesia was performed using fentanyl, remifentanil (0.2–0.3 μg/kg/min), rocuronium (0.6 mg/kg), and propofol with or without sevoflurane to facilitate endotracheal intubation. After endotracheal intubation, anesthesia was maintained with remifentanil (0.15–0.2 μg/kg/min), fentanyl, rocuronium and propofol or sevoflurane. Routine monitoring included electrocardiogram, pulse oximeter probe, automatic blood pressure cuff, rectal temperature, and bispectral index (BIS) (A-2000; Nihon Kohden, Tokyo, Japan). BIS values were maintained between 40 and 60 intraoperatively. All patients were turned into the prone flat position and their heads were supported in the neutral position with an LT-700 spinal frame with a horseshoe-shaped headrest (ISO Medical Systems Inc., Tokyo, Japan) to prevent any extraocular pressure.

IOP was measured in all patients with a Tono-Pen XL hand-held tonometer (Medtronic Solan, Jacksonville, FL, USA). To prevent dry eyes, we did not used eye lubricant but eye tape which we removed at every measurement. Calibration of the Tono-pen was carried out in the operating room before each operation. IOP was measured 10 min after induction of anesthesia in the supine position (baseline) and every 60 min after placing in the prone position until the surgery was complete. Of the IOP values in the prone position, the maximum IOP (max IOP) value was extracted. We measured bilaterally and selected the side which had the higher max IOP value. The interval between the start of prone positioning to the time at which IOP reached maximum value, was calculated as 'interval to max IOP'. According to max IOP values during prone positioning, patients were divided into 2 groups—group H with a max IOP value of ≥30 mmHg and group L with a max IOP of <30 mmHg. The medical history of the patients and intraoperative data were extracted from medical records and anesthetic charts. Total amounts of infusion, blood loss, and transfusion, duration of anesthesia, surgery and prone position, and the incidence of hypotension (systolic blood pressure <80 mmHg), hypertension (systolic blood pressure >140 mmHg) and hypercapnia (partial pressure of end-tidal carbon dioxide >40 mmHg), were recorded. The incidence of hypotension, hypertension and hypercapnia was defined if sustained for >15 min.

Statistical analysis

Data are expressed as median (interquartile range). To compare the 2 groups, statistical analysis was performed using the chi-squared test and Mann–Whitney U test, and $P < 0.05$ was considered as statistically significant. Receiver operating curve (ROC) analysis was performed to determine the cut-off points of each parameter. Logistic regression analyses were performed to identify predictive factors associated with an intraoperative IOP increase. Statistical analyses were performed by using Stat Flex ver6 (Japan) and Stata ver11 (Texas, USA).

Results

IOP was measured in all patients at all time points. No complications related to IOP measurements were noted intraoperatively or postoperatively. A total of 56 patients were included in this study—36 in group L and 20 group H. Demographic and intraoperative data are shown in Table 1. There were no statistically significant differences in demographic and intraoperative variables between the two groups.

The IOP data is summarized in Table 2. There were no significant differences in IOP values in the supine position before surgery between the groups. The IOP values 1 h after prone positioning (IOP1H) and max IOP values were significantly higher in the H group compared with those in the L group. The interval to max IOP was similar between the two groups. Changes in IOP values in the two groups are shown in Fig. 1.

Table 1 Demographic and intraoperative data

	Group L ($n = 36$)	Group H ($n = 20$)	P value
Age (years)	71 (51–77)	73 (63–75)	0.12
Sex (female)	20 (55 %)	9 (45 %)	0.57
Body mass index	24 (22–25)	24 (22–26)	0.23
Hypertension	15 (41 %)	11 (55 %)	0.34
Diabetes mellitus	4 (11 %)	6 (30 %)	0.082
Type of disease			0.56
Spinal canal stenosis	25 (69 %)	16 (80 %)	
Tumor	5 (13.9 %)	3 (15 %)	
Trauma	3 (8.3 %)	1 (5 %)	
Scoliosis	3 (8.3 %)	0 (0 %)	
Intraoperative data			
Anesthesia time (h)	4.3 (3.7–5.7)	4.3 (3.7–6.0)	0.42
Operation time (h)	3.1 (2.3–4.4)	3.3 (2.4–5.2)	0.41
Interval of prone position (h)	3.6 (2.7–4.6)	3.7 (2.9–5.7)	0.32
Total fluid volume (ml)	1,800 (1,250–2,500)	1,700 (1,363–2,250)	0.226
Total crystalloid volume (ml)	1,550 (1,088–2,200)	1650 (1,125–2,213)	0.197
Total colloid volume (ml)	0 (0−500)	0 (0–500)	0.750
Total blood loss (g)	133 (50–302)	222 (143–355)	0.324
Total blood transfusion (ml)	0 (0–0)	0 (0–0)	0.831
Lowest hemoglobin (g/dl)	11.0 (10.5–12.5)	11.5 (10.0–12.5)	0.797
Lowest temperature (°C)	36.0 (36.0–37.0)	36.0 (35.5–36.0)	0.644
Highest temperature (°C)	37.0 (36.0–37.0)	37.0 (36.0–37.0)	0.943
Hypotension (SBP <80 mmHg)	0 (0 %)	0 (0 %)	>0.999
Hypertension (SBP >140 mmHg)	1 (2.7 %)	1 (5 %)	0.668
Hypercapnia (ETCO2 >40 mmHg)	3 (8.3 %)	1 (5 %)	0.643

Data are expressed as median (interquartile range) or number (%)

Group L, maximum intraocular pressure <30 mmHg in the prone position. Group H, maximum IOP value of ≥30 mmHg in the prone position. The incidence was defined if sustained for >15 min

SBP systolic blood pressure, *ETCO2* partial pressure of end-tidal carbon dioxide

Table 2 Summary of results of intraocular pressure (IOP)

	Group L ($n = 36$)	Group H ($n = 20$)	P value
IOP in supine position before surgery (mmHg)	15.5 (13.0–19.0)	19.5 (17.5–21.5)	0.430
IOP 1 h after prone positioning (mmHg)	22.0 (19.0–23.0)	27.0 (24.5–30.0)	<0.001
Max IOP (mmHg)	26.0 (22.5–28.0)	33.0 (31.0–34.0)	<0.0001
IOP in supine position after surgery (mmHg)	16.0 (13.0–19.0)	19.0 (16.0–21.5)	0.031
Interval to maximum IOP (h)	2.5 (2.0–3.0)	2.9 (2.0–4.5)	0.22

Data are expressed as median (interquartile range)

Group L, maximum IOP <30 mmHg in the prone position. Group H, maximum IOP value of ≥30 mmHg in the prone position

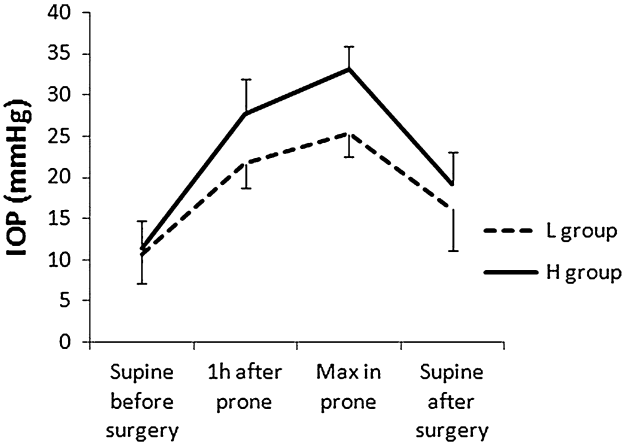

Fig. 1 Changes in intraocular pressure (IOP). IOP values in the supine position before surgery, 1 h after prone positioning, during prone position with maximum (max) value of IOP, and in supine position after surgery are shown. Data are expressed as mean ± SD. *Group L* max IOP <30 mmHg in the prone position. *Group H* max IOP value ≥30 mmHg in the prone position

Regarding IOP1H values, ROC analysis was performed to determine the cut-off value to predict an increase in IOP to ≥30 mmHg. Figure 2 shows the results of ROC analysis on IOP1H values (area under the curve 0.88). The results indicated that ≥23 mmHg of IOP1H was the best cut-off value to predict an intraoperative increase in IOP >30 mmHg (sensitivity 0.85, specificity 0.78). We

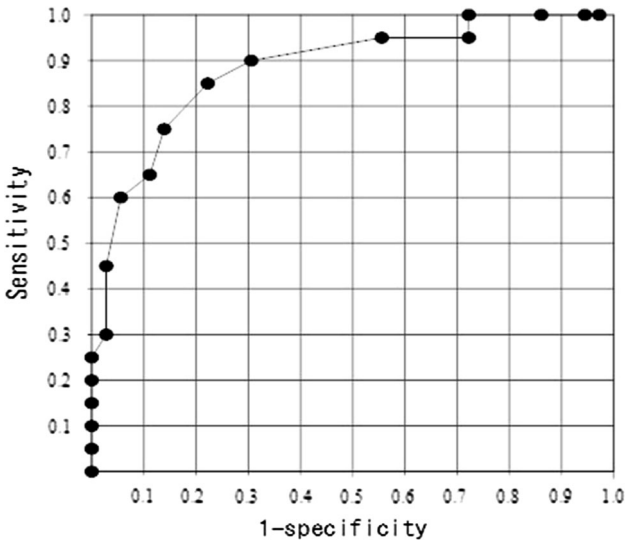

Fig. 2 Receiver operating curve (ROC) analysis on IOP values 1 h after prone positioning. The results indicated that an IOP1H value of ≥23 mmHg was the best cut-off value to predict an intraoperative increase in IOP >30 mmHg

transformed the continuous variable of IOP into a categorical variable based on this cut-off point. After selecting categorical data of IOP1H and body mass index as candidate variables, we put these variables into a logistic regression model by forced-entry methods. The results of the model chi-squared test and the Hosmer–Lemeshow goodness of fit test were $p < 0.0001$ and $p > 0.77$, respectively. IOP1 H was a significant predictor for max IOP of ≥30 mmHg during anesthesia (odds ratio 19.0, 95 % C.I 3.7–97.6). No symptomatic ophthalmological complications were noted in any patient postoperatively.

Discussion

The results obtained in this study showed that IOP values increased >30 mmHg in 20 of 56 patients (35.7 %) undergoing prone position spine surgery and that an IOP1H value of >23 mmHg was a predictive factor associated with an increased IOP >30 mmHg.

There have been several reports on intraoperative IOP changes during prone position surgery. Cheng et al. [1] showed that IOP values after prone positioning were significantly higher than those in the supine position before surgery after the induction of anesthesia (baseline). The IOP value at the conclusion of surgery in the prone position was 40 ± 2 (mean ± SD) mmHg, whereas the value at baseline was 19 ± 1 mmHg. Agah et al. [10] reported that the mean IOP value at the end of prone position surgery was 39 mmHg with a range of 37−40 mmHg and was significantly higher compared with after induction of anesthesia in the supine position (mean value 12.55 mmHg, range 12−13 mmHg) in patients undergoing percutaneous nephrolithotomy. Hunt et al. [11] also showed that IOP values (median) significantly increased from 11.5 mmHg (interquartile range 9–17.5 mmHg) after the induction of anesthesia to 30.5 mmHg (interquartile range 23.5–43.5 mmHg) at the end of prone position surgery in patients undergoing spine surgery. These results were consistent with those obtained in the present study in which IOP values increased >30 mmHg in 35.7 % of patients undergoing prone position spine surgery.

IOP1H values >23 mmHg were found to be a significant predictor for an increased IOP of >30 mmHg during prone position spine surgery. To the best of our knowledge, this is the first report to indicate that IOP values at an early time point during the operation can be used as a predictor of high IOP in anesthetized patients. An increase in IOP under prone positioning has been used to identify if patients had glaucoma—the IOP prone test. In this test, if an increase in IOP values within 1 h after prone positioning is >8–11 mmHg, patients may have glaucoma [9]. For anesthesiologists, the measurement of IOP at an early time point after prone positioning may be used as the IOP prone test. This technique may be acceptable rather than intermittent repetitive IOP recording throughout the surgical procedure. Repetitive IOP measurements are not easy and not practical due to the limited space for measurements. Prediction of an IOP increase may provide an opportunity for preventive strategies such as head-up positioning, shortening the operating time, and fluid restriction, etc.

It has been shown that longer duration in the prone position was associated with higher IOP values in patients under general anesthesia [1.9.12]. Cheng et al. [1] showed that IOP at the end of prone position surgery was correlated with total time spent in the prone position. IOP at the end of each procedure was measured after 320 ± 107 min in the prone position and was significantly increased in comparison with all previous measurements. Agah et al. [10] showed that there was a linear relationship between IOP and duration of the prone position ($R = 0.67; P = 0.001$); the IOP rose as the time elapsed. The mean IOP at the end of prone position surgery was significantly higher than the measurements at 10 min after prone positioning, although the duration of surgery was relatively short 79.75 ± 22.73 min (mean ± SD) in this study. In our study, any significant relationship between an increased IOP and the duration of prone position was not observed, although the interval to max IOP in group H was slightly longer compared with that in group L. Regarding the duration of surgery, further investigation with more cases would be required.

IOP is influenced by several factors including the volume of aqueous humor, choroidal blood, and vitreous

within the eye exerting an outward pressure, and sclera compliance and extraocular muscle tone exerting inward pressure. The mechanism in which IOP is increased in the prone position is not clearly determined. However, an increase in choroidal blood volume due to an increased venous pressure and increased extraocular pressure due to the swelling in extraocular tissues might be involved in an increase in IOP in the prone position. Although IOP is increased during prone position, the association with ophthalmological complications is unknown. Increased IOP may contribute to the development of ophthalmological complications including central retinal artery occlusion, retinal ischemic injury and deterioration of glaucoma. However, since the number of patients included in this study is relatively small, further study would be required to clarify the relationship between the IOP increase and ophthalmological complications.

There are several limitations in this study. First, we defined the groups according to IOP values of 30 mmHg. However, the value at which the IOP significantly influences the retinal blood flow is still unknown in patients undergoing prone position spine surgery under general anesthesia. In addition, we did not measure the retinal blood flow in this study. The results might be different if we used different cut-off values. Second, we did not measure IOP until 1 h after prone positioning. IOP values at earlier time points less than 1 h may be used as a predictor. Third, we did not evaluate whether the changes in IOP during prone position spine surgery contribute to the development of ophthalmological complications including asymptomatic lesions. Fourth, an IOP increase due to increased extraocular pressure, by the events which occurred following 1 h after prone positioning, cannot be predicted. Finally, patients with glaucoma were not included in this study. The results might be different in patients with preoperative increased IOP.

In conclusion, we evaluated the changes in intraoperative IOP values and the predictive factors associated with increased IOP during prone position spine surgery. The results indicated that the incidence of IOP increase >30 mmHg was relatively high (as much as 35.7 %) in this series of patients and that the IOP1H value of >23 mmHg was a predictive factor associated with increased IOP during prone position spine surgery. Measurement of IOP 1 h after prone positioning may be feasible and the results may provide an opportunity to treat and intervene in subsequent IOP increases. However, since the strategy for treatment and prevention of increased IOP in the prone position has not been established, further study would be required.

Acknowledgment This study was supported by a departmental source.

References

1. 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;95:1351–5.
2. Roth S. Perioperative visual loss: what do we know, what can we do? Br J Anaesth. 2009;103(Suppl 1):i31–40.
3. Lee LA, Roth S, Posner KL, Cheney FW, Caplan RA, Newman NJ, Domino KB. The American society of anesthesiologists postoperative visual loss registry:analysis of 93 spine surgery cases with postoperative visual loss. Anesthesiology. 2006;105 (4):652–9.
4. Riva CE, Grunwald JE, Petrig BL. Autoregulation of human retinal blood flow.An investigation with laser Doppler velocimetry. Invest Ophthalmol Vis Sci. 1986;27(12):1706–12.
5. Riva CE, Sinclair SH, Grunwald JE. Autoregulation of retinal circulation in response to decrease of perfusion pressure. Invest Ophthalmol Vis Sci. 1981;21(1 Pt 1):34–8.
6. Pillunat LE, Anderson DR, Knighton RW, Joos KM, Feuer WJ. Autoregulation of human optic nerve head circulation in response to increased intraocular pressure. Exp Eye Res. 1997;64(5):737–44.
7. Setogawa A. Kawai. Measurement of intraocular pressure by both invasive and noninvasive techniques in rabbits exposed to head-down tilt. Jpn J Physiol. 1998;48(1):25–31.
8. 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(2):152–6.
9. Kim TW, Park KH, Hong C. Dark-room prone-position test for intermittent angle closure. Korean J Ophthalmol. 2007;21(3): 151–4.
10. Agah M, Ghasemi M, Roodneshin F, Radpay B, Moradian S. Prone position in percutaneous nephrolithotomy and postoperative visual loss. Urol J. 2011;8(3):191–6.
11. 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(4):287–90.
12. Szmuk P, Steiner JW, Pop RB, You J, Weakley DR Jr, Swift DM, Sessler DI. Intraocular pressure in pediatric patients during prone surgery. Anesth Analg. 2013;116(6):1309–13.