



A Comparative Assessment of Intraocular Pressure in Prolonged Steep Trendelenburg Position Versus Level Supine Position Intervention

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Abstract

Background: The purpose was to evaluate a level supine intervention (LSI) during laparoscopic surgery in steep Trendelenburg position (Lap ST). Increased intraocular pressure (IOP) and decreases in ocular perfusion pressure have been monitored during Lap ST procedures. Peri-orbital swelling and venous congestion in addition to IOP may produce a low perfusion state in the eye, via a compartment syndrome mechanism potentially exacerbated by trabecular meshwork dysregulated pressure dependent outflow. Research in rodent models has confirmed that in the ST position IOP can increase to critical thresholds of > 40 mmHg and studies have determined that even brief 30-40 minute episodes of acute IOP elevations can result in retinal cell ganglion (RCG) dysfunction. A LSI for one 5 minute interval at the 60 minute time point was introduced and was hypothesized to normalize IOP.

Methods: A repeated measure prospective design was employed. After giving informed consent patients having Lap ST surgery were enrolled. IOP was measured at base in supine position, 30 minute intervals in ST and end of case in supine using a calibrated Reichert Tonopen XL tonometer over duration of the case. An anesthesia research team confined to five people was credentialed and after completing a series of inter-rater reliability tests collected data over a one year period. A control group maintained in the ST position was also monitored. Comparative analysis was completed.

Results: IOP in Lap ST without LSI at 120 minutes ranged 25-54 mmHg (31.6 ± 10.18). At end of case 11% returned to normal baseline (20.0 ± 6.16). IOP of LSI group ranged 10-33 mmHg (18.4 ± 4.98) at 120 minutes. End of case 75% of LSI patient's IOP's returned to normal baseline (13.9 ± 4.50). Analysis showed statistically significant decrease in mean IOP (P<.001).

Conclusions: An LSI can minimize the impact of lengthy Lap ST positioning on increasing IOP. Prevention of critical threshold > 40 mmHg should be a consideration during ST position procedures since current research has validated findings that elevated IOP may in fact lead to RCG dysfunction and could potentially lead to a postoperative visual loss event.

Key words: Intraocular pressure (IOP), posterior ischemic optic neuropathy (PION), ischemic optic neuropathy (ION), ocular perfusion pressure (OPP), postoperative visual loss (POVL), mean arterial pressure (MAP) - IOP = OPP

Introduction

This study was undertaken following an adverse event at a regional medical center in New England. The anesthesia team became concerned about ocular perfusion and peri-ophthalmic and intraocular pressure changes during laparoscopic abdominal surgery in the steep Trendelenburg position. The complication identified, postoperative visual loss (POVL) due to posterior ischemic optic neuropathy is a rare, but life-changing event. Following this adverse event a literature search was undertaken which established that there were at least 93 patients with POVL included in the American Society of Anesthesiology (ASA) POVL Registry [1]. All had general anesthesia with POVL reported after lengthy procedures that involved prone or lateral position, or coronary bypass surgery. An illustrative case involved an anesthesiologist who reported his own experience of POVL due to partial PION following spine surgery in prone position [2]. Although his procedure lasted 7.5 hours, no hypotension, significant blood loss or excessive fluid administration was

evident that could explain his POVL.

The case prompting this study was a laparoscopic lower abdominal procedure in the ST position, defined by a greater than 30 degree tilt below horizontal with the head in lowest position. In today's surgical environment the ST position assists the surgeon's visualization by displacing the bowel cephalad and away from the surgical field. However, in this position facial engorgement and edema can be quite significant. Progressive facial and peri-orbital edema, together with elevated IOP during these procedures led to a hypothesis that, under anesthesia in ST, cerebrovascular and ophthalmic circulatory autoregulation do not prevent increases in intraocular pressure. Increased peri-orbital swelling and venous congestion could contribute to possible peri-ophthalmic hypoperfusion. Perfusion of the eye, retina and posterior optic nerve could be compromised. When IOP exceeds ocular perfusion pressure during lengthy surgery in ST, a state of ocular and optic nerve hypoperfusion may lead to a critical decrease in ocular perfusion pressure of the

retina and ultimately progress to optic neuropathy and POVL.

Previous studies have shown that IOP is decreased during general anesthesia [3]. More recently it was shown that IOP increases significantly and doubles during general anesthesia in prone position [4]. IOP was measured over a 2 hour duration with the Tonopen XL instrument. A 2006 ASA review addressed these issues [5]. Subsequently, we showed sometimes dramatic changes in IOP during laparoscopic surgery in the ST position. Our initial 2005 ST group pilot study findings (presented at the 2007 ASA Assembly abstract/poster session) in which patients were monitored for a duration of 3 hours were later confirmed by Awad and colleagues in 2010 [6,7]. During these initial studies 6 cases, patients' operating room beds were returned to a level, supine position mid-procedure before the impact of ST over time could be evaluated. IOP levels did in fact drop on these cases. This was key to the researcher's recognition of potential preventive interventions and led the researcher to the current comparison study of the ST group and level supine intervention (LSI) group. The purpose of this study was to test the hypothesis and to illustrate the impact of a LSI on IOP during lower abdominal laparoscopic procedures.

Literature review

The incidence of POVL varies depending on the type of surgery. Baig and colleagues [8] projected a 0.2% incidence of POVL in spine procedures and .05% of all cases. Contributing medical conditions were hypertension (41%) and diabetes (16%). Identified in this series as contributing factors were hypotension, blood loss, anemia, excessive fluid replacement and prolonged surgery. An increasing number of POVL cases reported to the ASA National POVL Registry followed back surgery in prone position [1,5]. The actual incidence of POVL following these procedures is a conjecture based on reported cases. Reasons for this gap in the evidence include legal exposure and the fact that closed claims cases are often not reported until legal action is resolved as in the case prompting these studies, which may take up to seven years.

Riva [9] studied the autoregulatory process perfusing the optic nerve head (ONH).

He reports that the response to a decreased perfusion pressure is an increase in vascular capacitance and peri-orbital blood volume. This study was performed on awake patients while suction was applied to peri-orbital tissues. Baskaran *et al.* [10], studied yoga subjects who stood on their heads. They found that IOP doubled over a 2 hour duration with no deleterious effect. Both studies were performed on awake patients with the tonopen XL as the instrument measuring IOP.

Ischemic optic neuropathy (ION) may be caused by optic nerve hypoperfusion and hypoxia. Hayreh's [11] in depth review of retinal blood flow and autoregulation discussed the role of terminal arterioles regulating resistance to blood flow so that a relatively constant perfusion, capillary pressure and nutrient supply are maintained in spite of changes in perfusion pressure. Hayreh suggests that the rate of aqueous humor

drainage is increased thus, decreasing the episcleral venous pressure via this autoregulatory process. Ischemic disorders of the optic nerve head (ONH) typically take place in watershed zones where regional perfusion normally overlaps. Failure of oxygen supply is first observed at the vulnerable extreme edges of perfusion. Consequently a decrease in perfusion pressure of the posterior ciliary artery (PCA) or its branches can produce a more distal ischemic event involving the retina. Determinants of blood flow of the ONH depends upon local microvascular resistance, mean blood pressure (BP) and IOP or intracranial pressure (ICP), whichever is greater [11].

Baig and colleagues [8] reviewed POVL caused by PION after spine surgery. They suggested that the posterior optic nerve may be susceptible to decreased perfusion caused by increased venous pressure. It was noted that only small terminal pial arterial branches supply the midorbital optic nerve. They recommend that the head be elevated above the heart in order to prevent venous pooling in and behind the orbit. Pillunat and colleagues [12] described the blood flow variation in the 3 layers of the human optic nerve head (ONH). The superficial nerve fiber layer is nourished by the retinal circulation while the prelaminar and laminar layers are supplied by branches of the short posterior ciliary arteries (PCAs). They found that autoregulation of ONH circulation varied significantly. They identified an individual response to increased IOP that decreased blood flow by the time IOP reached 45-55 mmHg. Optic nerve head autoregulation failed below 30 mmHg. There is an assumption that the pattern of blood flow is the same in all eyes. However, upon examination of POVL patients there is marked interindividual variation. Flows have differed from right to left eye in the same patient [11]. Underlying disease entities and or marked arterial hypotension and hypertension may also disrupt this process [13]. Additional oxygen impairment caused by hypoxia, hypotension and anemia may contribute as well [14].

Lee and her colleagues [5] hypothesized that hypotensive ischemic optic neuropathy may be caused by a "compartment syndrome of the optic nerve" suggesting that "high venous pressure and interstitial tissue edema may compromise blood flow". A compartment syndrome is a condition in which increased pressure within a closed tissue compartment crosses a critical perfusion threshold beyond which a decrease blood flow to tissues within the compartment are compromised. By analogy the orbit is a confined relatively enclosed space as is described by Dunker and colleagues [15]. The optic nerve passes through the optic canal, a bony tunnel leading to the brain and they suggest that swelling in this inelastic space causes compression and can exacerbate ischemia which can perpetuate a cycle of injury. Within the potentially confined space of the orbit, ocular perfusion pressure (OPP) is defined as the mean arterial pressure (MAP) minus the IOP, when IOP exceeds jugular venous pressure.

Savitsky [16] commented that the orbital compartment syndrome hypothesis is speculative. He theorized that as orbital

pressure increases, orbital venous drainage may be impeded, so that this would diminish retinal and optic nerve perfusion pressures. He reported that irreversible optic nerve or retinal nerve damage may occur within 90 minutes of vascular insufficiency. Increased IOP associated with peri-orbital edema, venous hypertension and abnormal eye fluid mechanics, may also be a contributing factor to the hypoperfusion within the closed spaces of the orbit by decreasing the pressure gradient below a critical level at vulnerable portions of the optic nerve and retina [17]. Current research in rodent models cites alterations in ganglion-cell-related electroretinogram (ERG) potentials as a result of even brief acute increases in IOP (30 - 40 minutes at > 50 mmHg). Peak IOP was seen to be the principle determinant of functional loss in these studies [18]. Additionally, increased peri-orbital swelling and venous congestion secondary to trabecular meshwork dysregulated pressure dependant outflow may produce a low flow state in the eye, via this compartment syndrome mechanism [19].

In conclusion, Murgatroyd and Bembridge [20] reported that IOP must remain within normal ranges to maintain optimum anatomical conditions for refraction and, thus, vision. When IOP is significantly elevated by conditions like glaucoma or sustained ST, it may be important to maintain stable ocular perfusion by elevating MAP or decreasing IOP. Harris *et al.* [21], studied human autoregulation in 10 healthy subjects. Retinal flow was measured by doppler velocimetry. Individual retinal flow in response to increased IOP markedly varied. An IOP of 47 mmHg, in one subject, reduced flow to one third of normal, suggesting that human autoregulation may fail if IOP approaches within 40 to 45 mmHg of the mean arterial pressure. It was suggested that individual response to an autoregulatory plateau varied according to age, history of atherosclerosis, arterial hypotension and individual anatomic variation. These variations may explain why ophthalmic compartment syndrome, unlike intracranial or tissue compartment syndrome is not uniformly observed below specific ocular perfusion pressures.

Sappington and colleagues studied IOP-induced mechanical strain on retinal ganglion cells (RCGs). In RCG cultures, exposure to hydrostatic pressure activates mechano-sensitive transient receptor potential vanilloid 1 (TRPV1) resulting in a calcium influx, membrane depolarization and eventual cell death [22]. This local occurrence involving the impairment of the autoregulatory process has been studied by Kaiser and associates [23]. Factors affecting this process may be endogenous such as hyperlipidemia or exogenous such as drugs. Vasospasm is most noted in the ciliary or choroidal vessels or directly in the ONH. A drop in blood pressure or an increase in IOP can challenge the autoregulatory process and the system may decompensate, compromising the blood supply for a limited period of time.

The observations, in the current researcher's practice, of increased IOP and decreased OPP during procedures under anesthesia for laparoscopy in ST, suggest that prolonged ST

position could be a possible factor in the evolution of POVL. Linder and colleagues [24] assessed body position affects on IOP and visual function on awake patients. They described positioning as whole body, head-down tilt. The duration of head-down position was 2 hours and an incline of 6 degrees was maintained. IOP and biopotentials were measured repeatedly. Findings of IOP elevations 3 times baseline and subsequent transient neural dysfunction were associated with gravity inversion. The IOP elevations appeared to result from increases in choroidal vascular volume and episcleral venous pressure associated with the cephalad fluid shift.

Weber and colleagues [25] cite two incidents of PION involving the ST position during laparoscopic and robotic laparoscopic procedures. The need for ST positioning during lower abdominal robotic and laparoscopic procedures has dramatically increased over the past decade with over 853 hospitals in the United States using the da Vinci systems as of 2010 and internationally the numbers had doubled from 200 to 400 [26]. As was previously noted, there is a lack of reporting till closure of court case. Thus, the true incidence of PION involving robotic procedures may not be known since this is a fairly new technology. The learning curve interims extend duration of ST positioning and thus, may increase the incidence, since duration of time is a factor [6,7,25]. The intent of this study was in developing an intervention plan. For these reasons intraoperative interventions that might lower IOP intraoperatively were investigated.

Materials & Methods

Study Design

The study was a repeated measure quasi-experimental prospective design utilizing a patient group in ST position versus a supine intervention group. Full institutional review board (IRB) approval with informed consent and a mutual agreement from the University of Connecticut IRB was approved in 2009. IRB consent for measuring IOP with interventions of supine positioning for 5-7 minute intervals, dependent on time and increases in IOP, was obtained. A power analysis was estimated because there were no previous studies on which to base estimates of effect size.

Participants

Patients with a history of eye disease or eye surgery, diabetes, uncontrolled hypertension or vascular disease were excluded from the study. Procedures included were laparoscopic prostatectomy, bowel resections and pelvic gynecological procedures in ST for a minimum of 120 minutes surgical time.

The same exclusion criteria were met for the control group. Following written informed consent all patients having laparoscopic surgery in ST position were accepted if the surgeon was amenable to the proposed intervention. Thus, a subset of 6 surgeons were involved in both the ST group as well as the control group. Procedures performed on 37 control participants and 29 level supine intervention participants

were included, involving lower abdominal laparoscopic bowel, urological and gynecological surgical procedures in ST for a minimum of 120 minutes. No randomization since supine intervention was based on ability to intervene at 60 minute time frame conducive to surgical needs as well as if an elevated IOP value was obtained at that time. Surgeon was involved in decision making process as to timing for intervention.

Measures

Demographics: Data collection was initiated and documented on a data collection sheet in the holding area prior to surgery. Age, sex, height, weight, BMI, American Society of Anesthesia (ASA) physical status (Class 1-5), surgical procedure, medically indicated tests, fluid maintenance and vital signs were documented.

MAP (mean arterial pressure): An arterial catheter was placed preoperatively and MAP was measured after calibrating the transducer at heart level (mid axillary line) when the patients were supine. For measurements in ST position, pressures were measured with the transducer zeroed to level of carotid artery to reflect cerebral arterial pressure. OPP (ocular perfusion pressure) = carotid or mean BP-IOP in all positions [11]. Calculation of OPP was MAP minus IOP; but OPP was not considered as a dependent variable because carotid arterial pressure was elevated to maintain a target level of 80 mmHg. Thus, the only dependent variable was IOP.

Tonometer

An applanation tonometer was utilized for IOP monitoring (Reichert TONO-PEN® XL Applanation Tonometer™). The applanation tonometer is confirmed and has been accepted as a reliable IOP monitor in both awake and anesthetized patients as cited in the ophthalmic literature [9,10]. One study compared the tonopen XL with two other applanation devices. This IOP measurement technique was found to effectively track IOP and this device was determined to be the most accurate instrument for IOP measurement [27]. Measurements were obtained after lubrication with sterile Balanced Salt Solution (BSS) eye drops.

Procedures

A limited pool of five anesthesia caregivers were credentialed to monitor IOP under anesthesia in laparoscopic procedures in ST. Credentialed individuals took a video course and technique was observed on volunteers. Calibration was performed according to manufacturers instructions as per Reichert Tonopen XL manual and took place prior to each patient's data collection. The principal investigator (PI) then observed each of the five research assistants (RA's) in their observations on ten subjects to determine inter-rater reliability, individually and an additional 10 collectively as a group. The PI rating and the calibrated reading displayed in the tonopen window were the determinants of the correct

measure. Trochim's [28] inter rater reliability correlation method was used for 60 observations. A sterile cover was used on the head of the tonometer for each patient in preparation for monitoring. Physiologic OR monitors included a 5 lead EKG, a noninvasive blood pressure cuff and pulse oximeter. Inspired and exhaled gases were monitored by side-stream infrared gas analysis (Drager / Fabius GS). Early in this study, an approximation of external jugular venous pressure (CVP) was tracked in conjunction with arterial pressure and IOP at data collection interval. Later in the study, the need was determined by the anesthesia team based on the projected duration of the operation in ST procedure and underlying disease entities. Anesthesia protocol was standardized for all 37 control as well as 29 supined participants included in study. Midazolam 1-2 mg. was given in preoperative holding room. Anesthesia induction consisted of administration of fentanyl (1-2 ug/kg), propofol (2-3mg./kg.) and rocuronium (.07mg/kg) or vecuronium (.01mg-.015/kg) to facilitate endotracheal intubation. Muscle relaxant was used as needed throughout the case. Insufflation pressure was maintained at 14 mmHg through out procedures for all cases. General anesthesia was used in all with a combination of volatile and narcotic. Inhalation anesthetics used were sevoflurane or desflurane with 100% oxygen. Bispectral index monitoring was used to assess depth of analgesia so as to balance level of inhalational and narcotic according to need. Volume ventilation was adjusted to keep end-tidal carbon dioxide in the range of 30-39 mmHg through out the intraoperative period. Baseline IOP was determined after induction of anesthesia in the supine position by applanation tonometry. BSS eye drops were applied prior to each reading and ocular tonometry was repeated every 30 minutes, for the length of the surgery while in ST. Between measurements, the eyes were taped to prevent drying. Protective foam was placed over the face to prevent injury by items used in the surgical field. A protractor at the bedside determined the degree of ST, which ranged from 32-40 degrees. Fluid administration was adjusted by need. In general, fluid administration was limited to 200 ml/hour unless blood loss, hemoconcentration, metabolic acidemia or hypotension were noted [6]. Arterial or venous blood was drawn to assess acid-base status at periodic intervals during the procedures if blood loss or respiratory status was questioned by caregivers. When the patient was returned to supine position, a final IOP measurement was obtained prior to emergence from anesthesia. MAP was obtained for determination of OPP at the time of IOP reading.

The supine intervention group of 29 patients was monitored in the same manner except that, prior to the first hour of ST position, one 5-7 minute interval of supine intervention was trialed just prior to or following IOP measurement dependent on surgeons ability to time the intervention. A discussion took place and based on surgical needs the anesthesia caregiver initiated the reverse Trendelenburg positioning. The patient was then returned to ST for the duration of the case and vital

signs and IOP measurements were obtained upon return to ST position and every 30 minutes thereafter. A final IOP was measured under anesthesia on all subjects at the end of the case, upon return to the supine position prior to reversal agents and emergence from anesthesia.

In the recovery room and post-op day 1, patients were seen by anesthesia staff and asked about comfort, level of pain, eye discomfort, visual acuity and overall satisfaction with care.

Statistical Analysis

The data were analyzed using the SPSS system (version 17) with descriptive statistics including means, standard deviations and frequencies. Primary research questions were addressed with a repeated measure analysis of variance (RM-ANOVA) preceded by testing for sphericity. When evidence of non-sphericity was found the Greenhouse Geisser method was used for correction. Following RM-ANOVA a between group contrast was conducted at each study time point to determine when group differences were significant. The Bonferroni method was used to adjust for multiple comparisons across these post-hoc tests. Upon checking for homogeneity, a logarithmic correction was used to correct for evidence of heterogeneity.

Results

Final analysis was completed on the ST group with the subset of 37 patients: 21 were female and 16 were male, ages ranged from 31-78, with a mean of 55 years. Average body mass index (BMI) was $30 \text{ kg/m}^2 \pm 8.5$, ASA status was II (I-III range) ($2.2 \pm .47$). No underlying diabetes, vascular disease or glaucoma was present. The five ASA-III patients had stable cardiac or respiratory disease (see **Table 1**). The average case range was 3 hours. The surgeons involved were gynecological, urological and general surgical involving lower abdominal procedures. The supine intervention study group consisted of 29 subjects whose mean age is 55 with 18 being female and 11 being male. The average BMI was $28.5 \text{ kg/m}^2 \pm 5.8$, mean ASA status II (I-III range) ($2.2 \pm .47$) again the seven ASA III patients had stable cardiac or respiratory disease. Upon further review, 16 of the procedures were performed with the same general surgeon and the surgical procedures were a colon or sigmoid resection and 13 were gynecological procedures.

In the 37 ST participants, IOP significantly increased when patients were placed in a ST position (see **Table 2**). IOP increased from flat to 60 minutes in ST, ranging from 9-26 to 23-57 mmHg with a mean from 13.3 mmHg to 32.3.0 mmHg At 90 minute time frame IOP mean was 33.8 and to 35.7 at 120 minutes with a significant drop in OPP because MAP was held nearly constant (see **Figure 1**). OPP ranged from 50-82 to 21-75 mmHg at 120 minutes despite efforts to maintain MAP at or above 80. Between time comparisons showed mean difference

Table 1

Demographics	ST Group n = 37	Supine Group n = 29
Age range / Mean / SD	31-78/54/12.1	42-85/55/15.7
Gender		
M	16-43%	11-38%
F	21-57%	18-62%
Mean/SD	1.6/.48	1.6/.49
ASA ranges		
# ASA 1% of total	4-11%	2-7%
ASA 2% of total	28-76%	20-69%
ASA 3% of total	5-13%	7-24%
(stable cardiac or respiratory disease)		
Mean/SD	2.2/.47	2.2/.51
Range of BMI	kg/m ² /Mean/SD	22-44 / 28.5 / 5.6
BMI < 30 kg/m ²	#patients/%	22-62%
>30 kg/m ²		17-60%
Surgical Procedure		
Gynecological	15-40.5 %	13-45 %
Urological	7-19%	
Bowel	15-40.5%	16-55%

Table 2. Means & Standard deviations via repeated measure anova of Intraocular pressure over time. ST n=37 Supinen=29

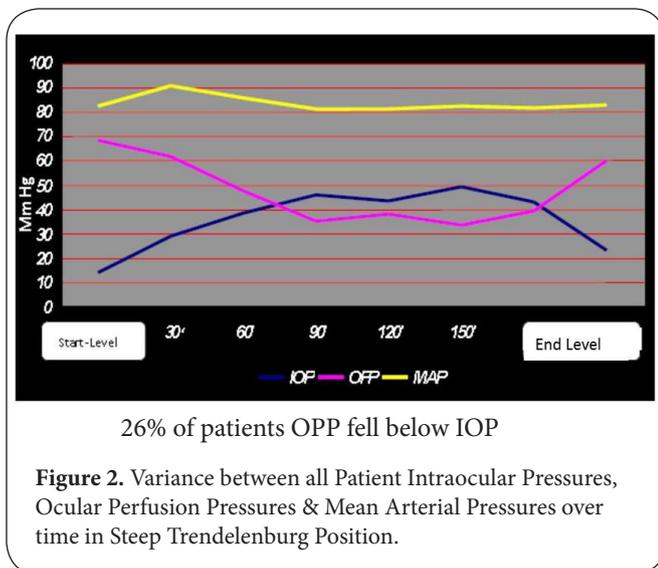
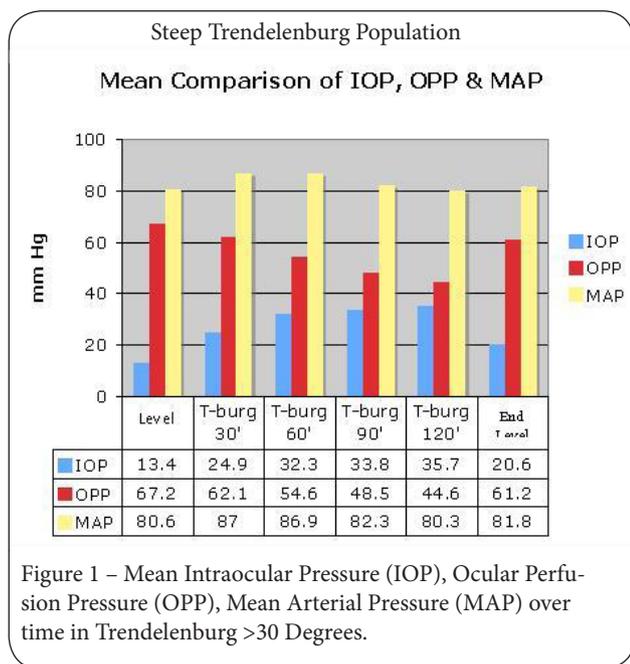
IOP/Time/Position	ST Group			Supin Group		
	M	SD	Range	M	SD	Range
IOP – Initial (Flat)	13.4	4.73	9-26	13.2	4.15	8-24
IOP – 30 (trendelenburg)	25.1	7.76	11-33	21.2	5.43	8-35
IOP – 60 (trendelenburg)	32.3	10.06	23-57	24.5	7.58	11-40
IOP – 90 (trendelenburg)	33.8	8.23	25-51	20.5	7.08	6-43
IOP – 120 (trendelenburg)	35.7	10.56	25-61	18.7	5.22	10-33
IOP – final (flat)	20.6	4.58	10-42	14.0	4.69	7-24
% Return to Baseline IOP	11%			73%		

** Supine intervention takes place just prior to /or following 60 - 90 minutes of ST position dependant on IOP measure and allowed time by surgeon during procedure.

significant <.005 level at all time periods except the 60 to 90 minute comparison. In the “recovery phase”, upon return to supine position, IOP did not return to baseline in 33 out of 37 cases (89%) **Table 2** patients. Ending IOP in supine was statistically significantly higher than baseline IOP.

In 26% of these cases, IOP tripled during two hours in ST. A graph of this group is displayed (see **Figure 2**). Physical signs of facial and orbital edema increased over time, although this was documented as an observation and not specifically measured. Ocular perfusion pressure dropped below IOP pressure as seen below in **Figure 2**. Several patients complained of blurred vision for a period of time following surgery, but POVL was not present.

The comparison values of the supine intervention group ranges are illustrated in **Table 2**. The range of initial IOP in the



supine group was from 8-24 mmHg (13.2 mean), IOP at 120 minutes was 10- 33 mmHg (18.8 mean) and the final IOP ranged from 7-23 mmHg (14 mean) compared to the ST group whose baseline initial IOP ranged 9-26 mmHg (13.4 mean), IOP at 120 minutes was 25-54 mmHg (35.7 mean) and at end of case range was 10-42 mmHg (20.6 mean). There was a significant decrease in IOP following one 5-7 minute supine intervention, with the greatest significance noted at the 90 and 120 minute time frame.

The average duration of time spent in the steep Trendelenburg position was 2.28 hours ± 2.1, Blood loss averaged 290cc. ± 175 (with a range from 50-600 cc.) and intraoperative hematocrits were the same in both groups with the mean

being 39.9 ± 4.5. Mean crystalloid infusion was 2890cc. ±729 (Lactated Ringers) with an initial fluid load of approximately 10 ml/kg and 300 cc. per hour on average thereafter. Sevoflurane was used in 53% and 47% desflurane in the combined population, with the supine intervention group using sevoflurane in 76% of their cases and the ST group using desflurane in 62% of the cases. 100% oxygen delivery was used in all but two cases (1 per group) where a 50% nitrous oxide in combination with 50% oxygen was used. Use of narcotics, muscle relaxants and propofol were all within mg/kg dose anesthesia guidelines as discussed in procedures. MAP pressure was maintained at an optimal 80 mmHg. as seen in **Figure 2**. End tidal sevoflurane and desflurane, end-tidal carbon dioxide (mean 35±3.5/ Supine group & mean 34±2.3/ ST group), and peak inspiratory values (mean 33±5.9/ Supine group & mean 34±5.7/ ST group) did not significantly change (P>.05).

Prior to conducting the RM Anova, IOP measurements were subjected to logarithmic transformation to ascertain homogeneity of variance. Testing results from the RM Anova revealed a statistically significant effect between time (F(3,113) =76.24, p<.001), $\eta^2(n^{72})=.40$ [29]. The p value reflects this correction. There was a statistically significant increase in mean IOP as time progressed utilizing a 5% threshold.

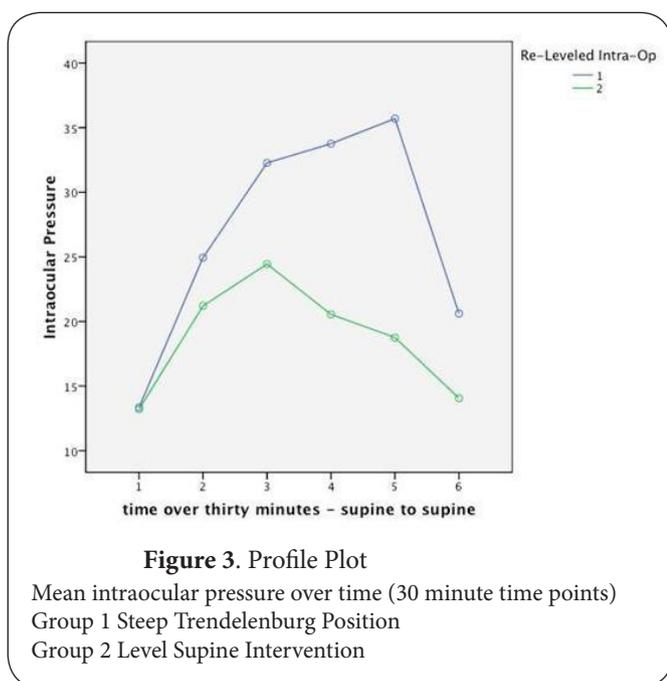
The comparative findings were analyzed after determining that IOP increased over time in the prolonged ST position. A logarithmic transformation in response to evidence of heterogeneity of variance was conducted. The testing results revealed a statistically significant interaction between time and group (F(3.7, 239) = 21.1, p<.001, $\eta^2(n^{92}) = .10$). Significant decrease in IOP occurred within 30 minutes of supine intervention with a return to baseline IOP in 21 out of the 29 subjects (73%). The profile plot illustrates the significance of these findings (**Figure 3**).

Following crosstabulation and Chi square analysis there were no statistically significant findings that gender, BMI, ASA status or type of surgical procedure were predictive of increasing IOP. A power analysis was performed with Cohen/ Wahlsten chart using an estimate of a medium effect size ($\eta = .10$) and an alpha level of .05 since there were no previous studies to base an actual effect size [29]. A sample size of 35 was determined to be appropriate for a RM-Anova with six time points.

Discussion

These data challenge the assertion that under anesthesia, during ST laparoscopic surgery, IOP will return to baseline over time because of an autoregulatory process. An increase in the rate of aqueous humour drainage decreasing the episcleral venous pressure does not limit IOP rise as Hayreh described [11].

In the ST group the highest ending pressures were seen in the >30kg/m¹⁰² population but this was not a statistically significant predictor of increasing IOP. That this was not noted



in the supine group suggests that BMI may be a factor as time progresses in the prolonged ST position. It is important to note that MAP was held constant the majority of time during all cases, and that systolic BP exceeded 100 torr; CVP was also monitored in the ST group to assess its potential relationship with IOP. A high normal CVP in most patients in ST position decreased the chance that elevated IOP was solely due to an isolated episcleral venous pressure increase. This is relevant to the findings that increased IOP with decreased OPP is directly related to the ST position over time. OPP below IOP suggests that increased IOP could, in fact, lead to a state of hypoperfusion with progressive ischemia within the eye and extra-orbital intracranial compartment. Thus, it is possible a time-dependent risk of injury from increased IOP may be associated with an ophthalmic ischemia and a putative ophthalmic compartment syndrome.

It should be noted that in studies completed on yoga participants who were not anesthetized found IOP level to be less than twice the normal baseline by second hour of cranial dependency [9,10]. This was not seen in our study and significant IOP elevation was noted at end of surgical procedures in ST position. This study was completed under anesthesia and typical anesthetic interventions were made to preserve OPP. Applanation tonometry was performed with the Tono-pen® XL in Baskaran's and in our studies [6,10].

This opens the question of whether various interventions can mitigate these changes. Baig and colleagues suggest that a treatment measure would be to place the head above the level of the heart. They have concluded the need to prevent venous pooling in the orbit and recommend rest stops to elevate the head [8]. Gilbert, a neuro-ophthalmologist, has

completed a literature review in 2008 that lead her to suggest that any interruption to a patient's blood flow autoregulation system could lead to POVL. She also states that duration of surgery in itself is an independent risk factor [30]. Our finding that introduction of a break for one 5 to 7 minute interval of supine position at an agreed upon time by surgeon and anesthesia team, have significantly changed rise and magnitude of IOP, suggests that the ophthalmic impact of sustained ST position can be mitigated. The fact that the two groups were similar in gender, BMI, ASA and underlying medical conditions should be noted (Table 1).

If IOP is measured during laparoscopic procedures in ST position, anesthesia caregivers can determine the need for an intervention. If sustained, increase in IOP that limits OPP may be an etiology of AION and PION following prolonged laparoscopic surgery in ST position. These findings suggest that this intervention is an effective means of reducing the impact of position on IOP and OPP. While the incidence of POVL following ST position is so low that no prospective study of this type could be undertaken, these surrogate endpoints predictive of low ophthalmic perfusion can mitigate this effect. In summary, by measuring IOP, practice changes can be implemented that may increase an ophthalmic margin of perfusion safety during prolonged surgery in the ST position.

Limitations

The fact that the study was contained to only one hospital may be a limitation. The same surgeons performed operations for the ST and the supine groups. This ensures that their skill in performing laparoscopic and robotic surgeries was fairly consistent. Monitoring was not confined to one specific surgeon's patients or to one procedure. This may be an unappreciated variation. The supine intervention group involved surgical procedures performed by a subset of these surgeons who were amenable to the intervention. The absence of randomization may also be a limitation. Randomization was not a choice following the initial pilot study. Once data showed that the effect of ST on IOP was mitigated by the proposed intervention an ethical choice about intervention on all future occurrences upon rise of IOP was made. History of glaucoma, diabetes or vascular disease was made based on patient and documented medical review. This may also be a limitation since screening for glaucoma and vascular disease is not specifically required prior to the surgical procedure.

Conclusions

This study supports the hypothesis that a level supine intervention at periodic intervals will minimize the impact of lengthy laparoscopic procedures in ST on IOP and OPP. There is a direct correlation between the duration of laparoscopic ST position surgery with increase in IOP. This may result in a reduction of OPP, sometimes to levels below IOP. A concern of caregivers is that OPP sustained below IOP may produce a state of hypoperfusion with obstruction of venous drainage

and may increase the risk of POVL. A preventive intervention, returning patients to supine position for 5-7 minute intervals after every two hours, provides a means of limiting this effect. The intervention time may be determined by surgeon and the anesthesia team depending on IOP levels, surgical needs and duration of time in ST position in order to maintain OPP. We conclude that a properly timed level supine interruption of ST position can minimize the impact of lengthy ST positioning on increasing IOP and may reduce the likelihood of future POVL caused by this mechanism for hypoperfusion.

Competing interests

The Authors declare that they have no competing interests.

Publication history

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