Original Article

Quantitative rise in intraocular pressure in patients undergoing robotic surgery in steep Trendelenburg position: A prospective observational study

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Abstract

Background and Aims: Raised intraocular pressure (IOP) is one of the known causes of anterior ischemic optic neuropathy. In the case of robotic urological-gynecological surgeries, patient is kept in steep Trendelenburg supine-lithotomy position. Aim of this study was to observe the quantitative rise in IOP in steep Trendelenburg position (>45°) in robotic-assisted prostatectomy and hysterectomy.

Material and Methods: After institutional ethical clearance and written informed consent, 100 patients undergoing robotic surgeries in steep Trendelenburg position were recruited for the study. IOP was measured at different time intervals in steep Trendelenburg position using Schiotz tonometer: Post intubation (T1), post pneumoperitoneum (T2), post steep Trendelenburg (T3), and rest readings were taken 30 min apart. T9 was taken 10 min after patient is made supine and parallel to the ground. Mean arterial pressure (MAP), positive inspiratory pressure (PIP), and end-tidal carbon dioxide (EtCO2) values were recorded at different time points. Descriptive analysis, linear regression analysis, and Freidman's nonparametric tests were used to analyze the results.

Results: Ninety-five patients were included for statistical analysis as five patients were excluded due to intraoperative interventions leading to alteration of results. Mean IOP at T1 was 19.181/18.462 mmHg in L/R eye. A gradual rise in IOP was observed with every time point while patient was in steep Trendelenburg position which reverts back to near normal values once the patient is changed to normal position 21.419/20.671: Left/right eye in mm of Hg. Uni and multiple regression analysis showed insignificant *P* value, thus no correlation between MAP, PIP, and EtCO2 with IOP.

Conclusion: Steep Trendelenburg position for prolong duration leads to significant rise in intraocular pressure.

Keywords: Aqueous humor, intraocular pressure, ocular tonometry, pneumoperitoneum, Robotic surgery, Schiotz tonometer, steep Trendelenburg position

Introduction

Postoperative visual loss (POVL) is a rare, well known, expected, and a devastating complication occurring in ~1/60 000–1/125 000 anesthetics.[1] Depending on the type of surgeries, i.e., whether ocular or nonocular (increased prevalence in cardiac, spine, head and neck, and some orthopedic procedures), causes may vary. It may be either transient or permanent visual loss. Most common causes include central retinal artery occlusion, ischemic optic neuropathy, and cerebral vision loss,[2] though triggering factor may be different.

Intraocular pressure (IOP) is well balanced and regulated pressure exerted on cornea by aqueous humour, disturbances

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in which may often be implicated in the development of glaucoma, uveitis, and retinal detachment. Raised IOP also known as ocular hypertension is one of the known causes of anterior ischemic optic neuropathy. According to the American Academy of Ophthalmology,[3] normal IOP is 10 millimeters of mercury (mmHg) to 21 mmHg. IOPs higher than 21 mmHg pose a risk for glaucoma, detached retina, and postoperative vision loss.[4,5] Extreme changes in patients' posture while undergoing surgery can cause a rise in IOP. Steep Trendelenburg position (an integral part of robotic urological-gynecological surgeries) is generally considered to be a head-down tilt of 30° to 45°.[6] The benefit of the Trendelenburg position is that it moves the abdominal viscera cephalad to improve visibility and surgical access to the abdominal and pelvic organs. However, there are potential harms associated with the Trendelenburg position. It leads to increases in IOP as the surgery progresses. Previous studies have shown increase in IOP[7] in patients undergoing robotic surgeries with position and pneumoperitoneum. They have correlated this rise of IOP to increase in mean arterial pressure (MAP)[8] or end-tidal carbon dioxide (EtCO2).[7] We aim to observe the quantitative rise in IOP in steep Trendelenburg position (>45°) along with pneumoperitoneum in robotic surgeries with increase in duration of surgery with an objective to find out its relation with confounding factors like intraoperative MAP, intravenous fluid administration, and EtCO2.

Material and Methods

After approval from Institutional Review board, this single centered, prospective, observational study was conducted from September 2016 to September 2018 in a tertiary care institute. The study was registered prior to patient enrolment at clinicaltrials.gov with ID NCT02646033. Written informed consent was obtained from all the subjects participating in this observational study. Due to apprehension and lack of acceptance for tonometry procedure in an awake state by most patients, after discussing with scientific committee of the hospital, it was decided to take baseline IOP value post intubation under anesthesia, as our aim was to show the rise in IOP with increase in duration of Trendelenburg position. Patients with preexisting glaucoma, eye surgeries, cataract, corneal diseases, and retinal vascular diseases which may affect IOP measurement, post coronary artery bypass grafting (CABG), and patients who are on medications which can change eye pressure were excluded. Considering 95% confidence limit, with 10% margin of error for a population of 1 lac, calculated sample size is 96. We have enrolled 100 patients undergoing robotic prostatectomies or hysterectomies of all age group with ASA grading 1 to 3 in this study. One day prior to surgery, every enrolled patient underwent visual acuity measurement of both eyes using Snellen's chart.

Anesthesia technique was standardized in all patients with respect to drug administration and monitoring. All the patients were given antiaspiration prophylaxis (tab. ranitidine 150 mg + tab. granicetron 2 mg orally) night before and on morning of surgery. IOP measurements were performed on each enrolled patient in both eyes using Schiotz tonometer. The tonometer was calibrated according to manufacturer's guidelines before each reading. Every time three readings were taken per eye, mean of which was then recorded. Inside the operation theater, standard ASA and bispectral index (BIS) monitoring were applied to all patients. All the patients were premedicated with inj. midazolam 1 mg i.v. followed by induction with inj. propofol (1–2.5 mg/kg) and inj. atracurium (0.08 mg/Kg) for muscle relaxation. Anesthesia was maintained by inj propofol at 100–200 μg/kg/min along with air-oxygen mixture (50:50) and sevoflurane (concentration adjusted to maintain BIS <60). After achieving a BIS <60 and adequate relaxation on neuromuscular monitor, patients were intubated with appropriate size endotracheal tube. Analgesia was maintained with inj. fentanyl 2 μg/kg, inj. morphine 0.1 mg/kg, and inj. paracetamol 1 g intravenously. Ventilation was maintained using closed circuit with fresh gas flow at 2 L/min using volume-controlled ventilation (PEEP = 5 mmHg; tidal volume at 6–8 mL/kg and respiratory rate at 12–18/min was adjusted to maintain EtCO2 between 35 and 40 mmHg and peak airway pressure <40 mmHg in head low position). Inj. ondansetron 8 mg iv was given intraoperatively for postoperative nausea and vomiting. Intraoperatively, restrictive fluid transfusion was followed as per institutional protocol for robotic surgeries. Up to 500 mL of balanced salt solution (plasmalyte-A) was transfused in each case. First IOP reading under anesthesia was taken 10 min after intubation (T1), followed by at T2, i.e., 10 min after creation of pneumoperitoneum for surgery (AirSeal device used for maintaining a constant intraabdominal pressure of 15 mmHg). T3 was then taken 10 min after patient is placed in steep Trendelenburg position. Next readings were taken at every 30 min interval till the patients are undergoing surgery, i.e., T4, T5, T6, T7, and T8 (just before patients' posture reversed to normal). Last reading, which was the primary outcome of the study (T9) was taken 10 min after patient is made supine and parallel to the ground.

Anesthetic agents were stopped at last suture of skin closure in both the groups. Extubation was done once BIS value reaches >90 along with spontaneous respiration after reversing with inj. neostigmine 2.5 mg and inj. glycopyrrolate 0.4 mg at a train of four ratio of 0.5. In postoperative period, visual acuity was again assessed at 6 h (100 patients) which was the secondary outcome of the study. Measurement from both eyes of each enrolled patients was included in the study. None of the patients had any significant blood loss (maximum recorded is 150 mL). Positive inspiratory airway pressure (PIP), EtCO2, and MAP were also recorded at all the time points.

Mean and standard deviation have been computed using descriptive statistics procedure. Freidman's nonparametric repeated measures, ANOVA test is used to show the change in IOP values at different time points during steep Trendelenburg position. The cut off "*P*" value <0.05 has been taken as significant. Univariate and multiple linear regression analysis was used to analyze the relationship between IOP and parameters like, MAP, PIP, and EtCO2. Data analysis has been done using IBM SPSS statistics 24, SPSS south Asia Pvt. Ltd.

Results

All 100 enrolled patients satisfied the inclusion-exclusion criteria. Inj. frusemide 10 mg was administered intravenously to five patients intraoperatively due to surgical reasons, followed by a fall in IOP readings. This is an incidental and important finding where injection lasix has brought down the IOP values, though more data is required to prove it. Thus, statistical analysis was conducted on rest of 95 patients only. Table 1 describes their demographic and clinical details. The average duration of patient lying in steep Trendelenburg position was 105 min. Table 2 shows the visual acuity of 95 patients pre and postoperatively as per Snellen's chart. Acuity remained same and showed no changes in vision postoperatively. Figure 1 shows the change and rise in IOP with increase in duration of Trendelenburg position. The mean IOP at T1 was 19.181/18.462 mmHg in left/right eye. A small rise of IOP in left eye was observed at T2 (post pneumoperitoneum) (19.724) vs. right eye where the pressure was same (18.462). Once patient is placed in steep Trendelenburg position (T3), gradual rise in mean IOP values were noticed in both eyes as the surgery progressed [Figure 1]. As T7 time point lies at 120 min post Trendelenburg position, whereas average duration of Trendelenburg position is 105 min (<120 min), T7 values could not be recorded in most of the patients and thus were excluded from statistical analysis. Maximum average IOP of 40.02/41.543 mmHg in left/right eye was recorded at T8, i.e., before patient is reversed to its normal supine position. Ten minutes post supination of patient, IOP decreases significantly– 21.419/20.671 in left/right eye in mm of Hg.

"D'Augostino-Pearson test" was used to assess normality of distribution of data. Since data was not normally distributed, Freidman's nonparametric repeated-measures ANOVA was used to analyze differences between related IOP values over different time points. Overall *P* value was significant for both eyes ($P < 0.00001$). Tables 3 and 4 show individual pairwise comparison of IOP values that were significantly different, $P < 0.05$ (tested according to Conover[9]). It implies that IOP differs significantly with respect to baseline and each other at different time points. Table 5 shows the relationship between left eye IOP and MAP, PIP, and EtCO2 using univariate and multiple linear regression analysis via beta coefficient and *P*- value. As both eyes have almost similar IOP values statistically, only left eye IOP values were used to show the results. Table 6 and Figure 2 show the change in MAP, PIP,

Table 1: Demographic and clinical details

Variables	Results
Male	
% of total 100 patients	32.63%
Mean age	60±8.21 years
Mean BMI	28.35±2.82
Mean duration of robotic prostatectomy	150±41.67 min
Female	
% of total 100 patients	68.36%
Mean age	58±8.31 years
Mean BMI	26.25±2.84
Mean duration of robotic hysterectomy	125±41.00 min
Mean duration for Trendelenburg position for robotic surgical procedure	105±30.45 min

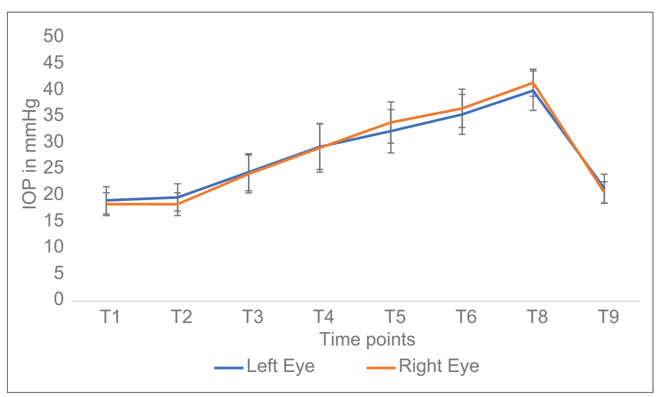

Figure 1: Change in intraocular pressure in both eyes with duration of surgery in extreme Trendelenburg position

Table 2: Visual acuity of all patients in both eyes

	Total patients=95 (a)	Percentage of individual group	Preoperatively	Postoperatively
Patients who are not using spectacles	45.26%	46.5% of (a)	6/6	6/6
		53.5% of (a)	6/9	6/9
Patients who are using spectacles	54.74%	90.38% of (a)	6/6	6/6
		9.68% of (a)	6/9	6/9

and EtCO2 with duration of surgery at different time points. None of the parameters shows significant variation with time.

Discussion

IOP is the fluid pressure measurement involving the magnitude of the force exerted by the aqueous humor on the internal surface area of the anterior eye. This pressure is a fine-tuned equilibrium between the production and drainage of aqueous humour by the ciliary body and the trabecular meshwork along with uveoscleral outflow respectively. Tonometry is a method used to determine IOP which is an important aspect in the evaluation of patients at risk of glaucoma.[10] It can be performed in a number of ways[11]: applanation tonometry, pneumatonometry, rebound tonometry, air-puff tonometry, and other methods like snapshot or SENSIMED triggerfish. We have used Schiotz tonometer (which is an indentation tonometer) in our study as it is inexpensive (as opposed to TonoPen which is much costlier), simple to use, durable, requires little maintenance, does not have electronics, does not require batteries, and can be stored for years between uses.

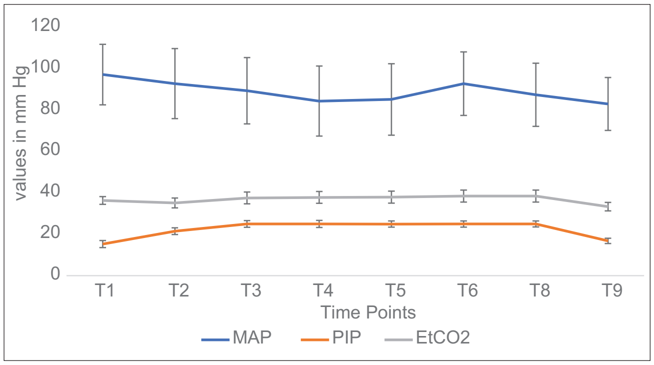

Figure 2: Change in mean arterial pressure, positive inspiratory pressure, and end tidal carbon dioxide at different time points

Table 3: Freidman's nonparametric ANOVA test to analyze changes in left eye IOP with duration of steep Trendelenburg position

Variable	Different (*P*<0.05) from variable nr
(1) IOP1_L	(3) (4) (5) (6) (7) (8)
(2) IOP2_L	(3) (4) (5) (6) (7) (8)
(3) IOP3_L	(1) (2) (4) (5) (6) (7) (8)
(4) IOP4_L	(1) (2) (3) (5) (6) (7) (8)
(5) IOP5_L	(1) (2) (3) (4) (6) (7) (8)
(6) IOP6_L	(1) (2) (3) (4) (5) (7) (8)
(7) IOP8_L	(1) (2) (3) (4) (5) (6) (8)
(8) IOP9_L	(1) (2) (3) (4) (5) (6) (7)

Table 4: Freidman's nonparametric ANOVA test to analyze changes in right eye IOP with duration of steep Trendelenburg position

Variable	Different (*P*<0.05) from variable nr
(1) IOP1_R	(3) (4) (5) (6) (7) (8)
(2) IOP2_R	(3) (4) (5) (6) (7) (8)
(3) IOP3_R	(1) (2) (4) (5) (6) (7) (8)
(4) IOP4_R	(1) (2) (3) (5) (6) (7) (8)
(5) IOP5_R	(1) (2) (3) (4) (6) (7) (8)
(6) IOP6_R	(1) (2) (3) (4) (5) (7) (8)
(7) IOP8_R	(1) (2) (3) (4) (5) (6) (8)
(8) IOP9_R	(1) (2) (3) (4) (5) (6) (7)

This study has tried to highlight the fact that steep Trendelenburg position (>45°), leads to gradual rise in IOP with time. All the patients in study had a normal baseline mean IOP of 19.181 mmHg in left and 18.462 mmHg in right eye. These values remain unchanged after creation of pneumoperitoneum indicating insignificant effect on IOP by raised abdominal pressure. As soon as the patient was placed in steep Trendelenburg position, IOP started to rise. Tables 3 and 4 also show significant difference between IOP values at different time points with each other and baseline (T1). Figure 1 clearly shows the continuous rise in IOP with maximum value at T8, i.e., 40.029 mmHg in left eye and 41.543 mmHg in right eye. This information is important, especially in patients suffering from glaucoma and ocular hypertension as it may convert an advanced surgical technique into an ocular nightmare for the patient along with medico-legal issues for treating physician. Awad *et al*.[7] has also shown the rise in IOP with head low position but the maximum quoted value in their study is 30 mmHg. This may be due to different types of measuring instruments used (Schiotz vs. TonoPen) and the angulation of patient with the floor. In our institute, table is fully tilted till its maximum (≥45°) for robotic surgery. More the angulation, more are the changes in IOP. A metanalysis by Sharon[12] shares the fact that most of previous studies have measured the IOP at ~28° angle but the pressure increases more with increase in degree and duration of head tilt.

It was also observed that the IOP value decreases to near normal value soon after patient is reversed in a horizontal

Table 5: Univariate and multiple linear regression analysis showing relationship between IOP of left eye with MAP, $EtCO_2$, and PIP

Parameters	Univariate linear regression analysis		Multiple linear regression analysis		
	Beta coefficient/Std. error	*P*	Beta coefficient/Std. error	*P*	95% Confidence interval
MAP	−0.29/0.613	0.480	−0.36/0.503	0.321	−1.965-0.827
PIP	0.74/0.527	0.037	−0.01/0.962	0.994	−2.679-2.663
$EtCO_2$	0.78/1.092	0.023	0.81/2.052	0.167	−2.237-9.155

Table 6: Change in mean arterial pressure, positive inspiratory airway pressure, and end-tidal carbon dioxide (mmHg) during surgery in Trendelenburg position

Time Points	Mean±Std. dev.		
	MAP	PIP	$EtCO_2$
T1	97.20±14.64	15.25±1.86	36.33±1.70
T2	92.84±16.97	21.48±2.37	35.13±1.64
T3	89.40±16.06	24.97±2.86	37.57±1.62
T4	84.38±16.93	24.98±2.87	37.82±1.70
T5	85.17±17.28	24.95±2.93	37.95±1.53
T6	92.81±15.37	24.97±2.89	38.45±1.49
T8	87.43±15.30	24.97±2.89	38.5±1.46
T9	83.00±12.79	16.8±2.07	33.37±1.27

position (within 10 min), i.e., 21.419 mmHg in left eye and 20.671 mmHg in right eye. These findings are consistent with the other studies done by Yuko *et al.*[13] and Sebastian *et al.*[14] (IOP value decreased from 33.9 to 21.8 mmHg). Some authors[13] have hypothesized that increased IOP can be the result of increased sympathetic activity, raised blood pressure, or carbon dioxide from pneumoperitoneum, all causing increased aqueous production, but none of it is conclusive. In our study, despite the fact that mean blood pressure, EtCO2, and airway pressure remained consistently at same level throughout the surgery [Table 6 and Figure 2], IOP levels still increased. Moreover, *P* value at multiple regression analysis was insignificant (>0.05) [Table 5] indicating that there was no relation between rise in IOP and change in for MAP, PIP, and EtCO2 during surgery in this study. Thus, we hypothesize that this rise in IOP is due to the obstruction in aqueous outflow in steep Trendelenburg position with normal production and absorption of aqueous fluid. As we have noticed that the normalization of IOP occurs within 10 min of normalization of patient posture, it can only be explained by sudden release of outflow obstruction of fluid leading to fall in pressure. This theory can be easily explained via the quantitative relationship[15]:

$Po = (F - U)/C + Pv$–tells that outflow obstruction can raise IOP.

Where:
- Po is the IOP in millimeters of mercury (mmHg)
- F is the rate of aqueous humour formation in microliters per minute (μL/min)
- U is the resorption of aqueous humour through the uveoscleral route (in μL/min)
- C is the facility of outflow in microliters per minute per millimeter of mercury (μL/min/mmHg)
- Pv is the episcleral venous pressure in millimeters of mercury (mmHg)

Hence, if C, i.e., outflow facility is less, IOP increases. If there had been an increase in production (high F) or decreased absorption (low U), it would have caused an increase in the total volume of aqueous humor leading to high IOP. But once the patient is made supine, this extra volume of aqueous will take time to clear out via absorption and thus cannot justify normalization of IOP in 10 min.

None of our patients showed any deterioration in their visual acuity as measured 6 h postoperatively using Snellen's chart. These findings are corroborative with the studies done by kyoichi *et al.*[16] and yukako *et al.*[17] where they have also analyzed the postop retinal and RFNL analysis for any damages but the results were normal.

Limitation of study

This study was conducted on small duration surgeries and can be extended on patients kept in steep Trendelenburg position for long hours (7–8 h). Also due to financial constraints, we have used the Schiotz tonometer which is a screening tool for raised IOP, though advanced technology can also be used for the same.

Conclusion

With the rise in the number of robotic surgeries, the issue of IOP remains neglected. This study has highlighted the fact that steep Trendelenburg position leads to gradual and significant rise in IOP which if persists for longer duration, may cause anterior ischemic optic neuropathy and thus blindness. Moreover, patients undergoing robotic urogynae surgeries belongs to older age group and are more prone for ocular complications. In current era, where patients are more informative and medico-legal issues are on rise, intraoperative blindness can be detrimental to both patient and doctor. Thus, we suggest inclusion of regular tonometric assessment of IOP in patients undergoing surgery in steep Trendelenburg position, both pre and postoperatively, so as to prevent any untoward ocular complication.

Ethical committee details

- Institutional Review Board Rajiv Gandhi Cancer Institute and Research Centre.
- RGCIRC/IRB/90/2015 – 21 September 2015
- Clinicaltrials.gov.in registration number - NCT02646033

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Nil.

Conflicts of interest

There are no conflicts of interest.

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