Implications for Postoperative Visual Loss: Steep Trendelenburg Position and Effects on Intraocular Pressure

Bonnie Lee Molloy, CRNA, PhD, APRN

Postoperative visual loss (POVL) is a rare but catastrophic complication after nonocular surgery. Previously, POVL has been reported in lengthy, prone, lateral, or cardiopulmonary cases, with extreme blood loss, hemodilution, and hypotension. The author's index case of POVL following a lengthy operation in steep Trendelenburg position (ST) prompted study of the relationship between intraocular pressure (IOP), mean arterial pressure (MAP), and time spent in ST.

A 3-year investigation of the relationship between IOP and ST procedures is reported. Ocular perfusion pressure (OPP) was calculated from IOP and MAP in supine position and at 30-minute intervals during ST. At start of surgery, IOP of 37 patients ranged from 9 to 28 mm Hg. At 120 minutes, IOP ranged from 25 to 54 mm Hg. The OPP ranged from 50 to 82 mm Hg at start of surgery and from 21 to 75 mm Hg after 120 minutes. Increased IOP and reductions in OPP in relationship to position change were statistically significant (P < .001), with OPP falling below IOP in 10 cases. Findings suggest a relationship between prolonged ST and reduced OPP, challenging the accepted view that cerebral and ophthalmic circulatory autoregulation prevents elevated compartment pressures and reductions in perfusion.

Keywords: Intraocular pressure, ischemic optic neuropathy, mean arterial pressure, ocular perfusion pressure, postoperative visual loss.

This study was undertaken after a 63-year-old patient became bilaterally blind following an elective laparoscopic prostatectomy in the steep Trendelenburg (ST) position, without observed hypotension, hemodilution, metabolic disturbance, or extreme blood loss. The complication was identified as due to a posterior ischemic optic neuropathy, and neither the anesthesia team nor the surgical team could establish a cause. Postoperative vision loss (POVL) is a rare but life-changing event. The clinical setting for this study was a medical center located in the northeastern United States.

Following this adverse event a literature search was undertaken. The author established that there were at least 93 cases of POVL registered in the American Society of Anesthesiology (ASA) Postoperative Visual Loss Registry. All cases had been performed using general anesthesia, with POVL reported after lengthy procedures that involved a prone or lateral position, or cardiopulmonary bypass surgery.1 Another illustrative case involved an anesthesiologist reporting his own POVL following spine surgery in prone position.2 Although the procedure lasted 7.5 hours, no hypotension, major blood loss, or excessive fluid administration was evident to explain his postoperative visual loss. He stated that he was unable to open his eyes until noon the next day secondary to swelling.2 He was in a prone Trendelenburg position for lumbar spine surgery.

The case prompting this study was in a ST position for 7.5 hours. Laparoscopic lower abdominal procedures in today's surgical environment assist the surgeon's visualization by displacing the bowel cephalad and away from the surgical field. Facial engorgement and edema can be quite substantial. The ST position is defined by a greater than 30-degree tilt of the bed below horizontal, with the head in lowest position. The progressive facial and 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 IOP and decreases in ocular perfusion pressure (OPP), which is mean arterial pressure (MAP) minus IOP. A previous study by Okuyama et al3 showed that IOP decreases during general anesthesia. In 2001 Cheng et al4 studied patients in prone positioning versus supine under general anesthesia and found that IOP doubled in the prone patient population. They measured IOP over a 2-hour duration with a handheld tonometer (Tono-Pen XL, Reichert Technologies, Depew, New York).

All patients in this study received general anesthesia with endotracheal intubation, and anesthesia was maintained with an inhalational anesthetic. A handheld application tonometer was used to measure intraocular (IOP) during lengthy operations in the ST position. This study measured IOP over a 3-hour duration in ST position during laparoscopic prostatectomy, bowel, and hysterectomy procedures while MAP was maintained at 80 mm Hg. The author's hypothesis was that if IOP exceeds OPP...
during lengthy surgery in ST, a state of hypoperfusion could lead to ophthalmic ischemia. Lee and colleagues\textsuperscript{5} address this issue in their 2006 review. The purpose of the current study was to describe the relationship between prolonged ST position (>30-degree head-down position) during lower abdominal laparoscopic procedures and determinants of ocular perfusion.

**Literature Review**

The incidence of POVL varies depending on the type of surgery. Baig and colleagues\textsuperscript{6} performed a 2007 literature review citing bypass procedures as having a 4.5% incidence of POVL and spine surgery a 2% incidence. Contributing medical conditions were noted as a history of hypertension (41%) and diabetes (16%). Intraoperative factors were hypotension, blood loss, anemia, excessive fluid replacement, and duration of the surgical case.\textsuperscript{6} The predominate number of POVL cases reported to the registry followed back surgery in prone position.\textsuperscript{4} Unfortunately, there is no prospective study examining how many patients sustain POVL following such procedures. Reasons for failure to report such cases include legal exposure and the fact that closed claims cases are often not reported until legal action is resolved, which may take up to 7 years. The 2003 Anesthesiology Update titled “Preventing Blindness” stated that 1 in every 10 neurosurgeons reported patients who have had POVL following lengthy back procedures.\textsuperscript{7}

Riva et al\textsuperscript{8} studied the autoregulatory process in the optic nerve head (ONH) and determined that in response to a decreased perfusion pressure, an increase in vascular capacitance occurs via an increase in blood volume to the ONH. This study was conducted on awake patients while a scleral suction cup was applied. Baskaran et al\textsuperscript{9} studied ONH. This study was conducted on awake patients while capacitance occurs via an increase in blood volume to the optic nerve head (ONH) and determined that in response to a decreased perfusion pressure, an increase in vascular

**Materials and Methods**

- **Study Design.** The study employed a repeated-measures, prospective design. Data were collected over 3 years. Institutional review board (IRB) approval for the initial subset of patients did not require consent. At the time of initial IRB an expedited review took place. Monitoring of IOP was instituted as a quality outcome
laparoscopic and robotic cases in ST. In the operating
dentialed in IOP monitoring performed anesthesia for
the tonometer while measurements took place.
and intubation a sterile cover was placed on the head of
patient's data collection. Following anesthetic induction
manufacturer's instructions and took place prior to each
dentation. Calibration was performed according to the
observed on several willing participants prior to cre-
mandated prior to credentialing anesthesia caregivers,
documented.

• Participants. All eligible patients scheduled to be in
prolonged ST position during surgical cases were accept-
ed. Patients with a history of eye disease or eye surgery
were excluded from the study, although their IOP was
monitored. Exclusion criteria also included patients with
history of diabetes, malignant hypertension, or vascular
disease. Participants underwent laparoscopic prostas-
tectomy, bowel, and hysterectomy surgical procedures
in ST for a minimum of 120 minutes, and monitoring
took place over a 3-hour period at 30-minute intervals
throughout the case.

• Demographic Measures. A data collection sheet
was created and implemented in the holding area prior
to surgery. Age, sex, height, weight, body mass index
(BMI), ASA physical status, surgical procedure, medically
to surgery. Experience

• Measurement of Mean Arterial Pressure and Intraocular
Pressure. An arterial catheter was placed preoperatively,
and MAP was measured after calibrating the transducer
at heart level when the patients were supine. When pa-
tients were in ST position, MAP was measured with the
transducer calibrated to the level of the carotid artery
to properly reflect mean cerebral perfusion pressure
(Perfusion Pressure = Mean BP – IOP).10 Calculation of
OPP was MAP minus IOP, but OPP was not considered
as a dependent variable because MAP is adjusted to main-
tain a target level of 80 mm Hg. Thus, in this study, the
only dependent variable was IOP.

A handheld applanation tonometer was used for IOP
monitoring (Tono-Pen XL). This instrument is con-
firmed as a reliable IOP monitor in both awake and anes-
ethetized patients, as cited in the ophthalmic literature.
(One such study compared this device to 2 other devices
and concluded that the Tono-Pen XL most closely re-
lected true IOP.16) A videotaped training session was
mandated prior to credentialing anesthesia caregivers,
and their technique with the handheld tonometer was
observed on several willing participants prior to cre-
dentialing. Calibration was performed according to the
manufacturer's instructions and took place prior to each
patient's data collection. Following anesthetic induction
and intubation a sterile cover was placed on the head of
the tonometer while measurements took place.

• Perioperative Procedures. Anesthesia caregivers cre-
dentialed in IOP monitoring performed anesthesia for
laparoscopic and robotic cases in ST. In the operating
room, monitors were placed, including electrocardi-
ogram (ECG) leads, a noninvasive BP cuff, and a pulse
oximeter. All ventilation was monitored by a sidestream
infrared gas analysis of agent concentration and cap-
nography. Upon initiation of the study an agreed-on
intervention by anesthesia staff included direct jugular
CVP monitoring and arterial pressure measurements.
This monitoring practice was dependent on the projected
duration of the procedure and the ST position as assessed
by the anesthesia provider. Baseline IOP was determined
after induction of anesthesia in the supine position by
applanation tonometry. Measurements were obtained
after lubrication with eye drops. Ocular tonometry was
repeated every 30 minutes for the length of the surgery
while the patient was in ST position. A protractor at the
bedside determined the degree of ST, which varied from
32° to 37°. Fluid administration was managed according
to provider judgment. In general, fluid was restricted
unless blood loss, hemoconcentration, metabolic acide-
ia, or hypotension was noted. 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 the care providers. When the patient
was returned to supine position at the end of the case, a
final IOP measurement was obtained prior to emergence
from anesthesia. The MAP was obtained for determina-
tion of OPP at the time of IOP reading.

In the recovery room and on postoperative day 1,
patients were seen by the anesthesia staff, and routine
questions were reviewed regarding comfort, level of pain,
visual acuity, and overall satisfaction with care. A data
sheet was maintained and any relevant postoperative
findings were noted.

• Statistical Analysis. The data were analyzed with
descriptive statistics, including means, standard devia-
tions, and frequencies. Primary research questions were
addressed with a repeated-measures analysis of variance
(RM-ANOVA) preceded by testing for sphericity. The
Bonferroni method was used to adjust for comparisons
across these post hoc tests.

Results
Initially, 43 patients were enrolled and monitored for a
minimum of 3 hours. Six patients were removed from the
study when their procedures were interrupted so that the
operating room tables were returned to a level, supine
position midcase, before the impact of ST over time
could be evaluated. The IOP levels did, in fact, drop in
these cases, and the results would have skewed the data
for patients undergoing lengthier procedures. Experience
with this subgroup suggested a potential intervention for
later studies.

Final analysis was completed with 37 patients: 21
women and 16 men. Ages ranged from 31 to 78 years,
with a mean of 50 years. Average BMI was 28 kg/m²,
with 15 patients having a BMI greater than 30 kg/m². Average ASA physical status was II (75%), with 11% having ASA I, and 14%, ASA III. No underlying diabetes, vascular disease, or glaucoma was present. Five ASA III patients had stable cardiac or respiratory disease. The average case duration was 3 hours. In the 37 subjects, both IOP and OPP significantly changed when patients were placed in a ST position. The surgical procedures performed were gynecologic, urologic, and general surgical involving lower abdominal procedures.

The mean IOP rose over time and did not return to preoperative levels by the second hour of surgery (Table 1). The IOP increased and remained elevated throughout the entire case. In the “recovery phase,” on return to supine position, IOP did not return to baseline in 34 cases. Between-time comparisons showed that the mean difference was significant, at a level of less than .001, at all time periods except the 60- to 90-minute comparison. The IOP increased significantly: from an initial mean of 14.8 mm Hg to 34.9 mm Hg at 90 minutes and to 35.2 mm Hg at 120 minutes (Figure 1). There was a significant drop in OPP, even while MAP held constant (see Figure 1). Vasopressors were used to support MAP during episodes of hypotension under anesthesia, although none of these 37 patients necessitated aggressive intervention with vasopressors.

The IOP increased from a range of 9 to 28 mm Hg in the baseline flat (supine) position to 25 to 54 mm Hg at 120 minutes in ST. The OPP ranged from 50 to 85 mm Hg to 21 to 63 mm Hg at the same time points (Table 2). Seventeen cases were followed up through 3.5 hours of surgery in ST. These patients showed a continued rise in IOP. The highest ending pressures were patient specific and were seen in the greater than 30 kg/m² population. Both IOP and OPP did not return to baseline at the end of the ST period for 33 of the 37 patients. Ending IOP in the supine position was statistically significantly higher than baseline IOP.

In 26% of these cases, IOP tripled within 2 hours in ST. A graph of this group is displayed in Figure 2.

### Table 1. Mean and Standard Deviations Via Repeated-Measures ANOVA of Intraocular Pressure Over Time Intraoperatively (N = 37)

<table>
<thead>
<tr>
<th>IOP measurement (min)</th>
<th>Position</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>Flat (supine)</td>
<td>14.8</td>
<td>4.71</td>
</tr>
<tr>
<td>30</td>
<td>Trendelenburg</td>
<td>25.5</td>
<td>8.42</td>
</tr>
<tr>
<td>60</td>
<td>Trendelenburg</td>
<td>34.9</td>
<td>10.44</td>
</tr>
<tr>
<td>90</td>
<td>Trendelenburg</td>
<td>34.9</td>
<td>8.42</td>
</tr>
<tr>
<td>120</td>
<td>Trendelenburg</td>
<td>35.2</td>
<td>10.32</td>
</tr>
<tr>
<td>Final</td>
<td>Flat</td>
<td>21.3</td>
<td>6.13</td>
</tr>
</tbody>
</table>

ANOVA indicates analysis of variance; IOP, intraocular pressure.

### Figure 1. Intraocular Pressure, Ocular Perfusion Pressure, and Mean Arterial Pressure Over Time in Trendelenburg Position Greater Than 30°

Data are shown as the mean (mm Hg). IOP indicates intraocular pressure; OPP, ocular perfusion pressure; MAP, mean arterial pressure; flat, supine; T-burg, Trendelenburg; prime sign, minutes.

Physical signs of facial and periorbital edema increased over time, although this was documented as an observation and not specifically measured. Ocular perfusion pressure dropped below IOP pressure in this greater than 30 BMI kg/m² patient population (see Figure 2). Several patients complained of blurred vision for a period following surgery, but POVL was not present. Blood loss averaged 250 mL, with a range from 50 to 600 mL. Average crystalloid infusion was 2,500 mL lactated Ringer’s solution, with an initial fluid load of approximately 10 mL/kg and 500 mL/h thereafter.

Prior to the RM-ANOVA, IOP measurements were subjected to logarithmic transformation in response to evidence of heterogeneity of variance. Testing results from the RM-ANOVA revealed a statistically significant effect of time: $F (3,126) = 53.94$, $P < .001$, $\eta^2 = .40$. The $P$ value reflects this correction. There was a
Table 2. IOP Measurements and OPP Calculations During Surgical Procedures in Steep Trendelenburg Position in a Sample of Patients (n = 18)

IOP indicates intraocular pressure; OPP, ocular perfusion pressure (calculated by mean arterial pressure minus IOP).

<table>
<thead>
<tr>
<th>Initial</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
<th>End</th>
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<tbody>
<tr>
<td>IOP</td>
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<td>OPP</td>
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<td>14</td>
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Figure 2. Variance Among All Patient Intraocular Pressures, Ocular Perfusion Pressures, and Mean Arterial Pressures Over Time in Steep Trendelenburg Position

In 26% of patients, their OPP dropped below their IOP.

IOP indicates intraocular pressure; OPP, ocular perfusion pressure; MAP, mean arterial pressure; flat, supine; prime sign, minutes.
significant correlation of increase in mean IOP as time progressed utilizing a 5% threshold. An estimated power analysis was performed because there were no previous studies on which to base an actual effect size.

**Discussion**

- **Limitations.** The fact that the study was performed at only 1 hospital may be a limitation. The experience of surgeons who have been performing laparoscopic and robotic surgeries was fairly consistent, however. Because monitoring was not confined to 1 specific surgeon's patients or to only 1 procedure, there may be an unappreciated bias.

The absence of glaucoma, diabetes, or vascular disease was made based on patient history. This also may be a limitation because screening for glaucoma and vascular disease is not specifically required prior to the surgical procedures included in this study.

- **Implications for Practice.** These data challenge the assertion that under anesthesia, during ST laparoscopic surgery, IOP will return to baseline over time through an autoregulatory process that increases the rate of aqueous humor drainage and decreases episcleral venous pressure, as Hayreh describes. When IOP is significantly elevated by conditions such as glaucoma or sustained ST, it may be imperative to maintain stable ocular perfusion by elevating MAP or decreasing IOP. Our observations of increased IOP and OPP changes during procedures performed with patients under anesthesia in ST led us to consider that the prolonged Trendelenburg position could be a possible factor in the evolution of POVL.

It is important to note that MAP was held constant via anesthetic levels and transient vasopressor intervention for most of the time during all cases, so that systolic BP exceeded 100 mm Hg during anesthesia. The CVP was also monitored to assess its potential relationship with IOP. A high normal CVP in most patients decreased the chance that elevated IOP was solely due to a rise in episcleral venous pressure. This bears a greater relevance to the assertion that increased IOP with decreased OPP is directly related to the degree of Trendelenburg position over time. The OPP below IOP suggests that increased IOP could, in fact, lead to a state of hypoperfusion with progressive ischemia in the closed compartment of the eye and extracranial intracranial compartment. Thus, it is possible that a time-dependent risk of injury from increased IOP may be associated with an ophthalmic ischemia and an ophthalmic compartment syndrome.

It should be noted that Riva et al hypothesized that an autoregulatory process should bring IOP down to near-normal levels when the head is dependent, and in a study by Baskaran et al of yoga participants who were not anesthetized, this process maintained IOP levels less than twice normal by the second hour of position variation. This, in fact, did not occur in the present study, and significant IOP elevation was noted at the end of surgical procedures in ST. This study was completed with patients under anesthesia and with typical anesthetic interventions made to preserve OPP. The instrument of measure was the Tono-Pen XL in both the study by Baskaran et al and in the current study.

Upon identification of elevated IOP readings intraoperatively, we can effect changes in position. An incidental finding was that in some patients with severe IOP elevation during ST, when the head of the operating table was returned to the level, supine position half way through the procedure, to meet procedural requirements, facial swelling, IOP, and orbital edema appeared to improve by the end of the procedure in contrast to subjects who were not leveled. Observations that elevation of IOP over time can be mitigated by transient, periodic change in position during surgery opens the question of whether interventions other than maintenance of MAP can decrease the effect of elevated IOP on cerebral perfusion pressure in ST position. Baig and colleagues suggest that a treatment measure would be to place the orbit 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. Gilbert, a neuro-ophthalmologist, conducted a 2008 literature review and determined that any interruption to a patient's blood flow autoregulation system can lead to POVL. She also states that duration of surgery in itself is an independent risk factor for POVL.

It is possible that by measuring IOP, one can predict when a change in the level of the table should be made so as to limit further IOP increases. A second intervention is that, because the calculation of perfusion and flow to the eye (OPP) is derived by obtaining IOP readings and subtracting them from the MAP, one can maintain OPP by elevating MAP. In summary, by measuring IOP, practice changes can be implemented to ensure the patient's ophthalmic safety.

**Conclusion**

These observations have spurred another study. Currently the subset of patients undergoing laparoscopy surgery in ST position is being observed with 5-minute “rest” periods after each hour of surgical time and/or a major rise in IOP. The surgeons are amenable to suspending laparoscopic surgery at such intervals. Data collection in this setting is ongoing, and the sequel to this study will support or contradict the hypothesis that this intervention will minimize the impact of lengthy laparoscopic procedures in ST position on IOP and OPP.

The current study has provided a direct correlation between the duration of surgery spent in ST with an increase in IOP, resulting in a reduction of OPP, sometimes to levels below IOP. There is a concern that OPP sustained below IOP may produce a state of hypoperfusion with obstruction to blood flow, or an “ophthalmic compartment syndrome,” and thus increase the risk of POVL.
REFERENCES


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