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ORIGINAL ARTICLE

Intraocular pressure change during laparoscopic sacral colpopexy in patients with normal tension glaucoma

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Abstract

Introduction and hypothesis The steep Trendelenburg position, high pneumoperitoneum pressure, and longer surgical time may lead to significantly increased intraocular pressure (IOP), which could result in unexpected eye disease complications, including perioperative visual loss (POVL). We monitored IOP to induce early laparoscopic sacral colpopexy (LSC) safely.

Methods This prospective study enrolled 39 patients with pelvic organ prolapse (POP), including 10 with eye diseases (6 with normal tension glaucoma and 4 with a narrow anterior chamber and normal range IOP). Enrolled patients underwent LSC under the same surgical settings involving a pneumoperitoneum of 10 mmHg and a Trendelenburg position of 15°. We measured IOP at seven time points during surgery and estimated IOP changes with time in patients with or without eye diseases.

Results All patients, with or without eye diseases, experienced significantly elevated IOP during LSC. There were no significant differences between these groups. The average maximal IOP reached 20 mmHg at the end of surgery, and recovered to baseline values with the patient in the supine position at the end of anesthesia. No patient had an IOP of >40 mmHg as a critical threshold during surgery, and no substantial clinical eye symptoms were seen after LSC.

Conclusions Laparoscopic sacral colpopexy using an pneumoperitoneum of 10 mmHg and a Trendelenburg position of 15° during a 3-h surgical period could be performed within a safe range of IOP.

Keywords Pelvic organ prolapse · Laparoscopic sacral colpopexy · Intraocular pressure · Glaucoma · Trendelenburg

Abbreviations

IOP	Intraocular pressure
LSC	Laparoscopic sacral colpopexy
NAC	Narrow anterior chamber angle
NTG	Normal tension glaucoma
POP	Pelvic organ prolapse
POP-Q	Pelvic organ prolapse quantification
POVL	Perioperative visual loss
RALP	Robot-assisted laparoscopic radical prostatectomy

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Introduction

Laparoscopic sacral colpopexy (LSC) has led to favorable outcomes in pelvic organ prolapse (POP) patients with minimal adverse events. The overall objective anatomical and subjective cure rates were 92% and 94.4% respectively [1], with decreased blood loss, a lower reoperation rate, and a shorter hospital stay compared with vaginal mesh repair [2]. However, LSC requires the Trendelenburg position, which is more technically challenging and requires longer surgical times. This includes frequent suturing for mesh attachment, in addition to linking between the anterior vaginal wall, the pelvic floor muscle fascia, and the anterior longitudinal ligament on the promontorium, which could lead to mesh-related unique complications [3].

A serious potential complication of laparoscopic surgery is perioperative visual loss (POVL). Two cases of POVL associated with the Trendelenburg position during robotic surgery have been reported; one involved complete bilateral visual loss and the other involved permanent loss of the bilateral inferior visual fields after a da Vinci robot-assisted procedure [4]. Furthermore, the Trendelenburg position during long

periods of general anesthesia has been reported to be a common factor of POVL [5]. Laparoscopic surgery with the patient in the Trendelenburg position also increased intraocular pressure (IOP), which can be associated with POVL [6, 7]. Although POVL was an isolated incident, symptomless visual field defects were detected in 28% of cases during robot-assisted laparoscopic prostatectomy (RALP) using a steep Trendelenburg position (25–30° tilt). This indicates that unknown, asymptomatic eye disorders can sometimes occur during surgery [8]. On the other hand, in radical prostatectomy, usually a steep Trendelenburg position held little or no risk for IOP increase in patients without pre-existing eye diseases [9]. Fortunately, to date, there have been no reports of POVL during LSC to our knowledge. However, according to a Japanese epidemiological survey (the Tajimi Study), 5% of the female population had glaucoma. The occurrence rates in patients 60–69 and 70–79 years old were 6.7% and 10.5% respectively, whereas that of undetected or untreated glaucoma patients was nearly 90% [10, 11]. Currently, no consensus regarding the IOP threshold value has been reached among surgeons, anesthesiologists, or ophthalmologists. However, The American Society of Anesthesiologists (ASA) recommended advising high-risk patients of the potential risk of POVL and, during "spine surgery," the head should be placed at the same level as the heart when possible [12, 13]. Therefore, we surveyed IOP during LSC while a patient with pre-existing eye disease was in the Trendelenburg position (15° fixed tilt from the horizontal), and a pneumoperitoneum pressure fixed at 10 mmHg.

Materials and methods

In this single center, prospective study, we recruited consecutive symptomatic prolapse patients (≥ pelvic organ prolapse quantification [POP-Q] stage II) who underwent LSC under total intravenous anesthesia by a single operator and a single anesthesiologist between April 2014 and September 2015 at our institution. Of the patients, 29 (control group) had no eye diseases, whereas 2 had normal tension glaucoma (NTG) and 1 had a narrow anterior chamber angle (NAC). Since September 2015, considering the burden on patients without eye diseases, IOP examination during LSC was restricted to patients with diagnosed eye diseases at preoperative ophthalmological evaluation. Therefore, an additional 4 patients with NTG and 3 with NAC were included and 54 patients without eye diseases were excluded until October 2016. Patients with NTG or NAC who underwent LSC at our institution, and who were diagnosed by an ophthalmologist to be favorable candidates for LSC, were classified into the NTG or NAC group. Eligible patients enrolled in this study consulted an ophthalmologist to evaluate their eye conditions (cornea, iridocorneal angle, optic nerve, and possible eye disorders) preoperatively. Patients with eye disorders (e.g., glaucoma with an elevated IOP, retinal disorders, or a past history of eye surgery), elevated IOP (>20 mmHg), and age >75 years were excluded. Also excluded were 4 patients attending another ophthalmic clinic, because of eye diseases that could not be treated by the ophthalmic preoperative evaluation at our institution, were also excluded, as was 1 patient diagnosed with a conical cornea that involved inadequate accuracy and reproducibility of IOP measurements using a tonometer.

The study protocol was approved by the institutional review board of the Japanese Red Cross Gifu Hospital (authorization number in 2015: O15111203), and this information was disclosed to the public (UMIN000026701). We explained the need for monitoring IOP measurements during surgery to prevent eye complications, and we obtained written informed consent from each patient at a preoperative meeting.

A single anesthesiologist, trained by an ophthalmologist, measured each eye's IOP using a tonometer during surgery. The mean of three IOP measurements and the average value for each eye were calculated to reduce variance. A handheld Tono-Pen AVIA® (Reichert, Buffalo, NY, USA) tonometer was used to measure IOP within a few seconds by contacting the surface of the cornea while the patient was supine under general anesthesia.

The IOP for both eyes was measured at seven time points: time 1 (5 min after anesthesia induction); time 2 (after pneumoperitoneum induction); times 3–6 (immediately, and 60, 120, and 180 min after Trendelenburg position initiation), and time 7 (5 min before patient extubation in the supine position). Time 1 was measured 5 min after induction of anesthesia to prevent IOP deterioration due to unstable blood pressure during the anesthesia induction period. The time 6 measurement was skipped occasionally to prepare for weaning of anesthesia based upon the patient's status before the end of surgery. We examined differences in peak IOP between the control and eye disease groups.

Laparoscopic sacral colpopexy was performed by a single, experienced surgeon following the protocol of Wattiez et al. [14]. To minimize the intraoperative intracorporeal pressure's influence on IOP variance, our operative protocol determined a pneumoperitoneum pressure of 10 mmHg with the patient in a 15° Trendelenburg position. Therefore, in cases of small intestine intrusion toward the Douglas pouch in a defined Trendelenburg position, we used the "Endoractor®" (Aquilant Surgical, Basingstoke, UK) to obtain an adequate surgical working space. This consisted of a long, slender, cellulose sponge used as an intestine fence through the trocar port to maintain a defined Trendelenburg position. The surgical procedure began with a deep dissection of the vesicovaginal space beyond the trigone level (just past the Aa point of the POP-Q) between the posterior bladder and anterior vaginal walls, sparing the bladder pillars to avoid injury to the ureter

or nerves. The rectovaginal space was dissected to an anorectal angle in the middle until the levator ani muscle (puborectalis muscle) fascia was reached on each lateral side. Two self-cut strip sheets of polypropylene mesh (Gynecare Gynemesh® PS, Ethicon or Polyform™; Boston Scientific, Marlborough, MA, USA) were fixed from the tip end of each dissected vesicovaginal and rectovaginal space to the promontory via the vaginal vault or cervical stump. The mesh was retroperitonealized in all patients to reduce the risk for postoperative bowel complications. None of the patients underwent a concomitant mid-urethral sling repair for postoperative stress urinary incontinence.

Follow-up protocol was as follows: the follow-up urogynecological checks for postoperative conditions were performed at 1, 3, 6, and 12 months, and then an annual hospital visit was scheduled. The ophthalmological postoperative evaluations, including visual field and optic nerve examinations for NAC and NTG, were performed using perimetry and the optical coherence tomography disc assessment at 1 month after surgery.

Data were expressed as the mean ± standard error or deviation of the mean depending on the data situation. The statistical significance of experimental observations was determined by the Wilcoxon or Chi-squared test with the level of significance set at $p < 0.05$. Statistical analyses were performed using JMP software, version 10.0 (SAS Institute, Cary, NC, USA).

Results

All 39 enrolled patients underwent LSC with a median 2-year follow-up. The patients' background characteristics are shown in Table 1. Mean age, body mass index, operative time, and overall blood loss were 63 ± 0.9 years (range, 54–75), 23 ± 0.4 (range, 17.1–27.4), 229 ± 6.1 min (range, 167–327), and 16 ± 4.9 mL (range, 5–180) respectively (Tables 1, 2). The ASA classification was 1 for 22 patients and 2 for 17. One patient, who had the longest surgical time and largest amount of bleeding, experienced bleeding from the left common iliac venous branch on the promontory, but did not require conversion to abdominal sacral colpopexy. The overall objective success rate was 95%. Two of the 39 patients had recurrent POP (1 had an anterior wall recurrence and 1 had apical recurrent prolapses). None of the patients had vaginal mesh erosion during the median 2-year follow-up (Table 2).

The IOP trends in the control group at the surgical time points are as follows. Between the pneumoperitoneum (T2) and Trendelenburg position (T3) time points, there was a significant increase in IOP (12.2 ± 1.6 vs 14.5 ± 2.1 mmHg respectively; range 9–15 vs 11–22 respectively; $p < 0.0001$). IOP increased in proportion to surgical time (T3 vs T4 vs T5: 14.5 ± 2.1 vs 17.0 ± 2.2 vs 18.4 ± 2.4 mmHg; range 11–22 vs 12.5–22.5 vs 14–22.5 mmHg respectively; $p < 0.0005$). The highest values were observed at the end of surgery, rising to a little less than twice that at anesthesia induction (T1 vs T6; 11.5 ± 1.4 vs 19.1 ± 3.0 mmHg respectively; $p < 0.0001$). In contrast, IOP until termination of anesthesia (T7) was 13.7 ± 2.9 mmHg (range, 9–18 mmHg) and returned to baseline values immediately (Fig. 1). IOP remained within normal range (IOP ≤ 20 mmHg) throughout LSC in 61.8% of the patients, whereas none of the patients had an IOP >40 mmHg as a critical threshold, including the NAC and NTG groups.

All patients, including those with NAC and NTG, had no complaints regarding eye inflammation or congestion in the postoperative period. At 1 month after surgery, ophthalmological checkup, including perimetry and optical coherence tomography disc assessment, was performed. No additional scotoma in the visual field and no changes in the thickness of the optic nerve were found according to the disc optical coherence tomography performed in patients, including those with NAC and NTG. No deterioration of the field of view and optic nerve was identified by the ophthalmologist on ophthalmological examinations in the study population.

Discussion

Laparoscopic sacral colpopexy gradually has become a common and more standardized POP repair procedure that reduces

Table 1 Characteristics of the 39 study participants

Variables ($n = 39$)	Eye diseases		Normal	p value
	NAC	NTG		
Number n (%)	4 (10)	6 (15)	29 (74)	
Age (years), mean ± SD (range)	68 ± 3.2 (65–71)	65 ± 3.7 (58–69)	62 ± 6.0 (54–75)	0.19
BMI (kg/m2), mean ± SD (range)	24 ± 1.4 (22–25)	23 ± 2.3 (21–27)	23 ± 2.8 (17–28)	0.93
ASA, mean ± SD (range)	1.5 ± 0.5 (1–2)	1.6 ± 0.5 (1–2)	1.4 ± 0.5 (1–2)	0.63

NAC narrow anterior chamber angle, *NTG* normal tension glaucoma, *BMI* body mass index, *ASA* American Society of Anesthesiologists physical status classification system

p value: Wilcoxon rank-sum test

Table 2 Surgical outcomes in eye diseases

Intraoperative data	Eye diseases		Normal	*p* value
	NAC	NTG		
Operative time, mean ± SE (range) (min)	226 ± 19 (167–275)	204 ± 15 (149–259)	230 ± 7.1 (174–327)	0.43
EBL, mean ± SE (range) (mL)	4.0 ± 1.0 (3–5)	8.0 ± 1.2 (5–10)	17 ± 6.0 (2–180)	0.16
Incidence of perioperative and postoperative adverse event				
Follow-up month, mean ± SE (range)	22 ± 3.6 (16–34)	32 ± 4.7 (18–49)	34 ± 1.1 (31–49)	0.02
Adverse event (*n*)				
Bladder injury	0	0	0	
Ureteral injury	0	0	0	
Bowel injury	0	0	0	
Vascular injury	0	0	1	
EBL > 100 mL	0	0	1	
Wound infection	0	0	0	
Ileus	0	0	0	
VTE	0	0	0	

EBL estimated blood loss, *VTE* venous thrombotic event, *SUI* stress urinary incontinence

p value: Wilcoxon rank-sum test, Chi-squared test

hospital stay and recovery time. However, longer operating times and a longer learning curve for the introductory period are the most significant disadvantages [15]. Introducing LSC at our institution was acceptable in view of the few perioperative complications except for a relatively long surgical time during this introductory period.

Although POVL rarely occurred, a long operation may induce it [16]. A systemic study between 1996 and 2005 reported that total cardiac, spinal, orthopedic, and general surgeries in the USA resulted in a 0.0235% incidence of POVL, with the highest rates involving spinal and cardiac surgeries (0.03% and 0.086% respectively) [17]. Although relatively rare, the recent development of surgical devices and procedures has resulted in reports of POVL after new surgical techniques (laparoscopic or robotic surgeries) involving prostatectomy [4, 7], inguinal hernia repair [18], and colorectal resection [19]. The prevalence and mechanism of POVL during robotic or laparoscopic surgery with the patient in the Trendelenburg position, including LSC, remain unknown, but the incidence of POVL in this patient population is increasing [7, 20]. Pinkney et al. [16] reported that patients undergoing laparoscopic surgery with a prolonged period in a Trendelenburg position are likely to experience increased IOP and are at risk for POVL. Further, use of the Trendelenburg position during surgery may result in a higher risk for increased IOP than for a pneumoperitoneum [16, 21]. Postoperative local visual field defects were detected in approximately 20% of patients without abnormal findings in the optic nerve head or retina, and the visual field recovered to normal within 3 months after RALP [8]. Recently, the ASA recommended advising high-risk patients of the potential risk for POVL during spinal surgery and that the head should be positioned at the same level as the heart when possible [12, 13].

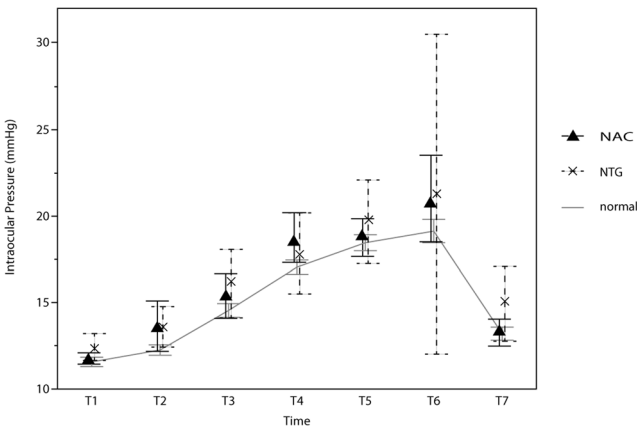

Fig. 1 Profile plot: comparison of mean intraocular pressure over time points in patients with and without eye diseases. Time 1 (5 min after anesthesia induction); time 2 (after pneumoperitoneum induction); times 3–6 (immediately, and 60, 120, and 180 min after initiation of the Trendelenburg position); and time 7 (5 min before patient extubation in the supine position). *NAC* narrow anterior chamber angle, *NTG* normal tension glaucoma

Our results were consistent with IOP trends, as reported previously for laparoscopic gynecological surgery [22], although the average duration of surgery in a previous report was much shorter than in our study (55.7 vs 229 ± 36 min), and the Trendelenburg position involved an unfixed tilt angle (range, 15–20°). Our patient population did not include those with various gynecological diseases, but was designed only for POP patients undergoing LSC. Our IOP result at the peak time point (T6) was lower (20 mmHg) than those in other reports (29.0 mmHg) using a steeper Trendelenburg position

(25° from the horizontal) during prostatectomy [6]. None of our patients, even those in the NTG and NAC groups, exceeded the cut-off IOP value at the critical threshold (IOP = 40 mmHg) [20].

Immediate assessment of the eyes could not be performed after surgery owing to the priority policy of postoperative general status. Although the eye condition may have recovered by the time an ophthalmological examination was performed, all patients, including those with NAC and NTG, had no complaints about eye inflammation or congestion in the postoperative period. At 1 month after surgery, no deterioration of the field of view and optic nerve was observed by the ophthalmologist on ophthalmological examinations in the study population. As a result, IOP managed within the critical threshold cutoff of 40 mmHg could be regarded as being within a "safe range."

These results suggested that shorter surgery time and smaller Trendelenburg position tilt angle might prevent IOP elevation, leading to decreased postoperative ocular complications. Moreover, this surgical protocol may demonstrate that even patients with NTG or NAC may not need IOP measurements during surgery. In fact, currently, real-time IOP monitoring is assumed to be uncommon during laparoscopic or robotic surgery. However, IOP measurement during surgery in patients with eye diseases, including NTG, remained controversial owing to a lack of evaluation criteria.

Our study had some limitations. First, the sample size was too small to evaluate POVL; thus, the incidence of POVL could not be provided. Second, we did not assess the field of vision because patients did not report disruptions in postoperative vision. Finally, we did not know whether a temporarily elevated IOP affected the visual symptoms or visual fields in the early postoperative period. However, IOP assessment in patients with pre-existing eye diseases undergoing an identical operation under the same surgical settings (fixed Trendelenburg position and pneumoperitoneum pressure) may be informative for marginal patients of robotic or laparoscopic surgical indication who carry some operative risks compared with standard operative candidates because of NTG or for other reasons. To the best of our knowledge, this has not yet been reported.

Normal tension glaucoma is a widely used term to classify diseases in patients with glaucomatous optic neuropathy, with or without visual field loss, whose pressures are within the normal range [23]. IOP is the most important modifiable risk factor for glaucoma onset and progression [10]. Glaucoma can occur during surgery, and transient but significant visual defects may be possible in patients even after an uneventful RALP [8]. Six patients with NTG and 4 with NAC were evaluated by an ophthalmologist at the preoperative examination, and our study reported IOP for patients with eye diseases. These patients tended to have higher IOP than those without glaucoma, but throughout the surgery they maintained IOP below the critical threshold [20]. Our 6 NTG patients demonstrated a reasonable prevalence, considering that a previous study reported asymptomatic glaucoma in 5–10% of the elder female population [10, 11]. However, to our knowledge, no studies have reported on laparoscopic surgery for the management of patients with NTG.

We were unfamiliar with an undiagnosed and pre-existing eye disorder, but the fact is that glaucoma was a common disease, according to a large glaucoma survey in Japan [10, 11]. These patients, who may have carried a potential perioperative risk for an eye disorder, could be candidates for LSC.

The supine intervention method (returning patients to a level supine position for 5–7 min mid-procedure) may help to manage IOP in cases of prolonged surgery in the Trendelenburg position. This technique demonstrated that the mean IOP increased up to 35.7 mmHg at 120 min of surgery and temporally decreased to 18.8 mmHg [24]. Nearly the same results were obtained concerning an immediate decrease in IOP related to body position change in normal patients or those with eye disease in our study.

A Valsalva maneuver occurs frequently during normal daily activities and leads to increased IOP; it is standardized to achieve a pressure of 40 mmHg and maintained for 15 s [25]. Continuous IOP elevation during surgery unlike that of daily life related to POVL remains controversial. There were no patients with POVL in the study, as the patient population was small. In addition, surgical settings were mild (pneumoperitoneum pressure 10 mmHg and Trendelenburg position 15°). Any data concerned with POVL could not be provided, and continuous IOP elevation during surgeries related to POVL remains controversial. Not all patients with and without eye diseases were able to undergo an operation with intra-abdominal pressure of 15 mmHg and steeper Trendelenburg position in actual daily medical examination. For these marginal candidates for the operation, for example, patients with NTG, high pneumoperitoneum pressure or a steep Trendelenburg position seemed to be unfavorable. We believe that this report will provide some helpful and insightful suggestions and information for marginal patients with indications for robot-assisted laparoscopic surgery.

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Compliance with ethical standards

Conflicts of interest None.

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Patient consent Written consent was obtained from the patients included in the study.

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