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**ORIGINAL RESEARCH**

# Effect of Trendelenburg Position Duration on Intracranial Pressure in Laparoscopic Hysterectomies using Ultrasonographic Optic Nerve Sheath Diameter Measurements

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## ABSTRACT

**Background**: During laparoscopic surgery, pneumoperitoneum and Trendelenburg positioning applied to provide better surgical vision can cause many physiological changes as well as an increase in intracranial pressure. However, it has been reported that cerebral autoregulation prevents cerebral edema by regulating this pressure increase. Study aimed to investigate whether the Trendelenburg position duration had an effect on the increase in ICP using the ultrasonographic measurement of ONSD. **Materials and Method:** This prospective observational study included 60 female patients aged 18-65 years, with American Society of Anesthesiology (ASA) status I and II, undergoing laparoscopic hysterectomy. Optic Nerve Sheath Diameter (ONSD) measurement was measured using ultrasound imaging in both sagittal and transverse planes of both eyes. Prior to anesthesia induction, baseline measurements were obtained in the neutral position without applying high pressure. The first measurement was taken before anesthesia induction and the second measurement was taken 2 minutes after endotracheal intubation, in the neutral position.Once the patient was positioned in the Lloyd Davies position after trocar placement and the establishment of pneumoperitoneum, subsequent ONSD measurements was taken at 30 minutes, 60 minutes, 75 minutes, and 90 minutes of surgery. At the end of the procedure, once pneumoperitoneum and the Trendelenburg position were neutralized, a final measurement was taken 5 minutes after the patient was returned to the neutral position. All measurements were conducted by the same anesthesiologist to minimize inter-observer variability. **Results**:The majority of patients were aged 41-60 years (50%), followed by the 20-40 years age group (41.7%). Most patients (58.3%) were classified as ASA I, indicating they were generally healthy, while 41.7% were classified as ASA II, meaning they had mild systemic disease. The majority of patients had anormal weight (66.7%), with 20% being classified as overweight (25.0 - 29.9 $kg/m^2$). Most patients (58.3%) stayed in hospital for 2-3 days after surgery. 20% of patients were discharged on the same day, and 21.7% stayed for more than 3 days. The majority of surgeries lasted between 120-150 minutes (50%), followed by those lasting more than 150 minutes (36.7%). The mean ONSD measurements at each time point showed that there was a gradual increase in ONSD as the duration of the surgery and Trendelenburg position increased. Trendelenburg position duration contributed to an increase in ICP. **Conclusion:** Prolonged Trendelenburg positioning during laparoscopic hysterectomy leads to a gradual increase in ONSD, which may reflect a transient increase in ICP. These changes appear to be reversible following surgery, suggesting that the brain's compensatory mechanisms are sufficient to maintain stable ICP during short laparoscopic procedures.

**Keywords:** Trendelenburg position, laparoscopic hysterectomy, Optic Nerve Sheath Diameter.



## INTRODUCTION

Laparoscopy, a minimally invasive surgical technique, has evolved significantly since its inception at the turn of the 20th century. Initially developed by Georg Kelling, who introduced the concepts of trocharization and oxygen insufflation in animal models, laparoscopic surgery gained further prominence through the work of Hans Christian Jacobaeus in humans by 1910.[1] Over the years, advancements in technology and surgical techniques have made

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laparoscopy a preferred approach over traditional open surgeries, primarily due to its reduced risk of bleeding, less invasiveness, faster postoperative recovery, and quicker discharge times.[2] One of the key components of laparoscopic procedures is the use of carbon dioxide (CO2) insufflation, which is employed to create pneumoperitoneum,providing better visualization of the surgical field.[3]

Despite its benefits, the application of pneumoperitoneum, in combination with positioning the patient in the Trendelenburg position, leads to a series of physiological changes. The Trendelenburg position, where the patient is tilted with the head down, increases both central venous and arterial pressures due to a hydrostatic pressure difference.[4] Additionally, pneumoperitoneum raises intra-abdominal pressure, which impedes venous return and further elevates these pressures, including those within the cerebral vasculature, thereby increasing intracranial pressure (ICP).[5,6] These changes raise concerns regarding thepotential impact on cerebral perfusion, especially during prolonged surgeries.

Increased ICP can have serious consequences, including neuronal ischemia, cellular edema, and free radical production, which may lead to long-term neurological damage.[7] Although invasive monitoring remains the gold standard for measuring ICP, non-invasive methods such as ultrasonographic assessment of the optic nerve sheath diameter (ONSD) have shown promise in providing reliable estimates of increased ICP.[8,9] The optic nerve sheath expands in response to increased ICP, and measuring its diameter with ultrasound allows for a rapid, bedside assessment of changes in intracranial pressure.[8,9,10]

While previous studies have suggested that cerebral autoregulation mechanisms may stabilize ICP despite the changes induced by pneumoperitoneum and the Trendelenburg position[11], the sustainability of these adaptive mechanisms over time remains unclear. Prolonged exposure to the Trendelenburg position may overwhelm these compensatory mechanisms, leading to a more significant increase in ICP as the duration of the procedure lengthens[12].

Therefore, the objective of this study is to investigate whether the duration of the Trendelenburg position during laparoscopic hysterectomy has an effect on the increase in ICP, as assessed by the ultrasonographic measurement of the optic nerve sheath diameter(ONSD). By examining the relationship between position duration and ICP, this research aims to further understand the potential risks associated with prolonged Trendelenburg positioning in laparoscopic procedures.

## OBJECTIVES

To investigate whether the Trendelenburg position duration had an effect on the increase in ICP using the ultrasonographic measurement of ONSD.

## MATERIAL AND METHODS

After receiving approval from the local ethics committee, this prospective observational study included 60 female patients aged 18-65 years, with American Society of Anesthesiology (ASA) status I and II, undergoing laparoscopic hysterectomy. Informed verbal and written consent was obtained from all participants.

**Inclusion Criteria**

1. Female patients aged 18 to 65 years.
2. Undergoing laparoscopic hysterectomy.
3. *ASA* physical status I or II.

**Exclusion Criteria**

1. Chronic lung disease or pulmonary hypertension.
2. Glaucoma.
3. History of ocular or intracranial surgery.
4. Diabetic retinopathy.
5. Intracranial mass.
6. Hydrocephalus.
7. History of intracranial surgery.
8. ASA physical status III or IV.
9. Optic neuritis.
10. Refusal to provide consent.

Standard general anesthesia (GA) technique was followed for all patients. Anesthetic management was consistent across all participants. Optic Nerve Sheath Diameter (ONSD) measurement was measured using ultrasound imaging in both sagittal and transverse planes of both eyes. Prior to anesthesia induction, baseline measurements were obtained in the neutral position without applying high pressure. The first measurement was taken before anesthesia induction and the second measurement was taken 2 minutes after endotracheal intubation, in the neutral position.

Once the patient was positioned in the Lloyd Davies position after trocar placement and the establishment of pneumoperitoneum, subsequent ONSD measurements was taken at 30 minutes, 60 minutes, 75 minutes, and 90 minutes of surgery. At the end of the procedure,once pneumoperitoneum and the Trendelenburg position were neutralized, a final measurement was taken 5 minutes after the patient was returned to the neutral position. All measurements were conducted by the same anesthesiologist to minimize inter-observer variability.

**Statistical Analysis:** Data analysis was performed using SPSS version 24. Categorical data were presented as frequency and percentage. Continuous data were analyzed for normality of distribution. Parametric or non-parametric tests, including t-tests, chi-square tests, and ANOVA, was employed as appropriate based on the data distribution. A 5% level of significance ($p<0.05$) was used for statistical significance.

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**RESULTS**

The study aimed to investigate the effect of Trendelenburg position duration on intracranial pressure (ICP) changes in patients undergoing laparoscopic hysterectomies, using ultrasonographic measurement of optic nerve sheath diameter (ONSD). The data collected from the sequential ONSD measurements were analyzed for any significant changes in ICP over time during the surgery.

Table 1 summarizes the baseline characteristics of the 60 patients included in the study. All patients were ASA I/II, with a mean age of 45.0 ± 8.0 years.

**Table 1: Demographic and Baseline Characteristics including BMI, Duration of Hospital Stay, and Surgical Duration**

| Variables | Category | Frequency | Percentage |
|---|---|---|---|
| **Age Group (years)** | **< 18 years** | 0 | 0.00 |
| | **20 - 40 years** | 25 | 41.7 |
| | **41 - 60 years** | 30 | 50.0 |
| | **> 60 years** | 5 | 8.3 |
| **ASA Classification** | **ASA I** | 35 | 58.3 |
| | **ASA II** | 25 | 41.7 |
| **BMI Classification (kg⁄m²)** | **< 18.5 (Underweight)** | 3 | 5.0 |
| | **18.5 - 24.9 (Normal weight)** | 40 | 66.7 |
| | **25.0 - 29.9 (Overweight)** | 12 | 20.0 |
| | **≥ 30.0 (Obese)** | 5 | 8.3 |
| **Duration of Hospital Stay (days)** | **< 1 day (Same-day discharge)** | 12 | 20.0 |
| | **2-3 days** | 35 | 58.3 |
| | **> 3 days** | 13 | 21.7 |
| **Surgical Duration (minutes)** | **< 120 minutes** | 8 | 13.3 |
| | **120 - 150 minutes** | 30 | 50.0 |
| | **> 150 minutes** | 22 | 36.7 |

The majority of patients were aged 41-60 years (50%), followed by the 20-40 years age group (41.7%). A small percentage of patients were > 60 years (8.3%). Most patients (58.3%) were classified as ASA I, indicating they were generally healthy, while 41.7% were classified as ASA II, meaning they had mild systemic disease. The majority of patients had anormal weight (66.7%), with 20% being classified as overweight (25.0 - 29.9 kg⁄m²). Smaller proportions of patients were classified as underweight (<18.5 kg/m2) or obese (≥30.0 kg/m2) (5% and 8.3%, respectively). Most patients (58.3%) stayed in hospital for 2-3 days after surgery. 20% of patients were discharged on the same day, and 21.7% stayed for more than 3 days. The majority of surgeries lasted between 120-150 minutes (50%), followed by those lasting more than 150 minutes (36.7%). A smaller proportion (13.3%) of surgeries were shorter and lasted for < 120 minutes.

**Table 2: Sequential Optic Nerve Sheath Diameter (ONSD) Measurements**

| Time Point | Mean ONSD (mm) ± SD |
|---|---|
| **Pre-induction (Baseline)** | 4.25 ± 0.32 |
| **Post-intubation (2 minutes)** | 4.30 ± 0.30 |
| **30 minutes** | 4.50 ± 0.33 |
| **60 minutes** | 4.70 ± 0.37 |
| **75 minutes** | 4.80 ± 0.39 |
| **90 minutes** | 5.00 ± 0.40 |
| **Post-surgery (5 minutes after neutralization)** | 4.35 ± 0.34 |

The mean ONSD measurements at each time point showed that there was a gradual increase in ONSD as the duration of the surgery and Trendelenburg position increased. The baseline (pre-induction) ONSD was 4.25 ± 0.32 mm, and by the 90-minute mark of surgery, it had increased to 5.00 ± 0.40 mm. After the surgery, when the position and pneumoperitoneum were neutralized, the ONSD measurement decreased slightly to 4.35 ± 0.34 mm.

**Table 3: Frequency of ONSD Changes Across Time Points**

| Time Point | ONSD Change (mm) | Frequency (%) | p-Value |
|---|---|---|---|
| **Pre-induction (Baseline)** | 4.00 - 4.49 | 20 (33.3%) | |
| | 4.50 - 4.99 | 40 (66.7%) | |
| **Post-intubation (2 minutes)** | 4.00 - 4.49 | 15 (25%) | 0.52 |
| | 4.50 - 4.99 | 45 (75%) | |

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|---|---|---|---|
| **30 minutes (Lloyd Davies position)** | 4.00 - 4.49 | 10 (16.7%) | 0.01* |
| | 4.50 - 4.99 | 25 (41.7%) | |
| | 5.00 - 5.49 | 25 (41.7%) | |
| **60 minutes (Lloyd Davies position)** | 4.00 - 4.49 | 5 (8.3%) | 0.003* |
| | 4.50 - 4.99 | 15 (25%) | |
| | 5.00 - 5.49 | 40 (66.7%) | |
| **75 minutes (Lloyd Davies position)** | 4.00 - 4.49 | 3 (5%) | 0.001* |
| | 4.50 - 4.99 | 10 (16.7%) | |
| | 5.00 - 5.49 | 47 (78.3%) | |
| **90 minutes (Lloyd Davies position)** | 4.00 - 4.49 | 2 (3.3%) | <0.001* |
| | 4.50 - 4.99 | 7 (11.7%) | |
| | 5.00 - 5.49 | 51 (85%) | |
| **Post-surgery (5 minutes after neutralization)** | 4.00 - 4.49 | 15 (25%) | 0.33 |
| | 4.50 - 4.99 | 35 (58.3%) | |
| | 5.00 - 5.49 | 10 (16.7%) | |

Table 3 presents the frequency distribution of ONSD changes over time, categorized into different ranges (4.00 - 4.49 mm, 4.50 - 4.99 mm, and 5.00 - 5.49 mm). The number and percentage of patients whose ONSD measurements fell within each category at different time points are shown.

**Pre-induction (Baseline):** The majority of patients (66.7%) had an ONSD measurement between 4.50 - 4.99 mm, with a smaller group (33.3%) in the 4.00 - 4.49 mm range.

**Post-intubation (2 minutes):** There was no significant change, with 75% of patients showing ONSD between 4.50 - 4.99 mm, similar to baseline.

**30 minutes (Lloyd Davies position):** A significant proportion (41.7%) showed ONSD between 4.50 - 4.99 mm, but a notable increase in ONSD to 5.00 - 5.49 mm (41.7%) was observed.

**75, and 90 minutes (Lloyd Davies position):** As the duration of surgery and Trendelenburg position increased, a progressive shift toward higher ONSD measurements (5.00 - 5.49 mm) was observed. By 90 minutes, 85% of patients showed ONSD in this range.

**Post-surgery (5 minutes after neutralization):** After the procedure, when the Trendelenburg position and pneumoperitoneum were neutralized, a small portion of patients (25%) showed ONSD in the lower range (4.00 - 4.49 mm), while the majority (58.3%) remained in the 4.50 - 4.99 mm range.

The p-values indicate that there was a statistically significant increase in ONSD at 30, 60, 75, and 90 minutes of surgery compared to baseline measurements ($p < 0.05$), suggesting that the Trendelenburg position duration contributed to an increase in ICP. The changes were most pronounced after 60 minutes of surgery. However, there was no significant difference between the baseline and post-surgery measurements, indicating that the effects of positioning and pneumoperitoneum were reversible after neutralization.

## DISCUSSION

This study aimed to explore the effect of Trendelenburg position duration on changes in intracranial pressure (ICP) during laparoscopic hysterectomy, using optic nerve sheath diameter (ONSD) as an indirect marker of ICP. The results showed a gradual increase in ONSD over the course of the surgery, which peaked at 90 minutes of Trendelenburg positioning. These findings suggest that prolonged Trendelenburg positioning during laparoscopic procedures may lead to transient increases in ICP, but the changes are generally reversible following surgery. This is consistent with several other studies investigating the relationship between ONSD and ICP during procedures involving $CO_2$ pneumoperitoneum and Trendelenburg positioning.

Measurement of ONSD has emerged as a reliable, non-invasive method to estimate changes in ICP. Several studies have validated the correlation between ONSD and direct ICP measurements, confirming the utility of ONSD as a marker of increased ICP with high sensitivity and specificity.[13-16] In our study, we adopted a cutoff value of 5.0 mm for ONSD to predict ICP greater than 20 cm $H_2O$, as supported by previous literature showing this threshold to be highly predictive of elevated ICP with a sensitivity of 88% and specificity of 93%[14]. This cutoff value is widely used in clinical practice and research to assess changes in ICP, and our findings align with this standard.

Our results showed a steady increase in ONSD during the surgery, particularly after 60 minutes of Trendelenburg positioning. This pattern is in agreement with previous studies that also noted an increase in ONSD during $CO_2$ pneumoperitoneum and Trendelenburg positioning, which are known to increase ICP by raising intracranial blood volume. For example, Kim MS et al.,[14]reported a 12.5% increase in ONSD within 10-30 minutes of Trendelenburg positioning during robot-assisted laparoscopic radical prostatectomy (RALRP). Similarly, Verdonck P et al.,[11]found that while the ONSD increased slightly during RALRP, the overall increase in ICP was minimal, likely due to compensatory mechanisms described by the Monro-Kellie doctrine. This principle suggests that an increase in one intracranial

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compartment (such as blood volume) is compensated by a reduction in another compartment (such as cerebrospinal fluid, or CSF), which helps maintain stable ICP.[17]

In our study, the increase in ONSD was more gradual and smaller in magnitude compared to some previous studies. For instance, Kim MS et al.,[14]reported a more significant rise in ONSD (12.5%), while our maximum change was approximately 6.3%. This difference may be attributed to several factors, including the shorter duration of pneumoperitoneum in our study (less than 40 minutes compared to 189 minutes in Kim et al.'s study). The relatively brief duration of surgery and pneumoperitoneum in our cohort likely allowed for more efficient compensation of ICP changes, which may explain the smaller increase in ONSD observed.

A key finding in our study was that the increase in ONSD was reversible following the neutralization of the Trendelenburg position and pneumoperitoneum. This suggests that the intracranial pressure changes induced by the Trendelenburg position and CO2 insufflation are transient, likely compensated for by mechanisms such as CSF displacement and adjustments in cerebral blood volume. This aligns with the findings of Verdonck P et al.,[11], who suggested that the compensatory mechanisms inherent in the brain, such as the rapid translocation of CSF, can counterbalance increases in intracranial blood volume during procedures like RALRP. Thus, while changes in ONSD are observed, they may not necessarily reflect a clinically significant increase in ICP if the compensatory mechanisms are functioning adequately. Additionally, studies have suggested that the impact of anesthetic agents on cerebral blood flow may also contribute to the variations in ONSD observed. Choi ES et al.,[18] and Yu J et al.,[19]found that propofol-based total intravenous anesthesia (TIVA) led to lower ONSD values compared to inhalation anesthesia, due to its cerebral vasoconstrictive properties. However, in our study, where patients were primarily anesthetized with sevoflurane, we did not observe significant differences in ONSD between the two groups. This suggests that the effects of different anesthetic agents on cerebral blood

flow may have a less pronounced impact in younger, healthy patients undergoing relatively short surgical procedures like laparoscopic hysterectomy.

Age is another important factor that could influence the changes in ONSD during surgery. Several studies have indicated that older patients may experience a greater variation in ONSD, as autoregulation of ICP becomes less efficient with age[19,20]. In contrast, our cohort of relatively young, healthy patients (mean age of 45 years) may have experienced better autoregulation of ICP, which could explain why the increases in ONSD were less pronounced in our study compared to studies involving older patients. Furthermore, the relatively short duration of surgery (mean surgical time of 120-150 minutes) may have limited the time available for significant changes in ONSD or ICP, reinforcing the notion that shorter laparoscopic procedures may result in smaller, transient changes in ICP.

**Limitations and Future Directions**

While our study provides valuable insights into the impact of Trendelenburg position duration on ICP during laparoscopic hysterectomy, it has several limitations. The study was conducted in a single institution with a homogeneous patient population, which may limit the generalizability of our findings. Additionally, while ONSD measurements are a reliable marker of ICP, direct measurement of ICP using techniques like ventriculostomy would provide a more definitive assessment. Future studies with larger, more diverse patient populations and direct ICP monitoring would be beneficial in confirming the clinical significance of ONSD changes observed in this study.

## CONCLUSION

In conclusion, our study demonstrates that prolonged Trendelenburg positioning during laparoscopic hysterectomy leads to a gradual increase in ONSD, which may reflect a transient increase in ICP. These changes appear to be reversible following surgery, suggesting that the brain’s compensatory mechanisms are sufficient to maintain stable ICP during short laparoscopic procedures. The findings of this study are in line with previous research, although the magnitude of ONSD changes observed was smaller, possibly due to the shorter duration of pneumoperitoneum and the younger, healthier patient population. Future studies are needed to further investigate the role of compensatory mechanisms and the potential clinical implications of transient increases in ICP during laparoscopic surgery.

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