RESEARCH PAPER

Comparison of the impact of neutral and steep Trendelenburg positions on end-tidal co_2 during pneumoperitoneum in robotic-assisted laparoscopic surgeries

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ABSTRACT

Background: Robotic-assisted laparoscopic surgeries frequently require steep Trendelenburg positioning (25–40°) in nearly 70–90% of pelvic procedures to facilitate optimal surgical exposure. Creation of CO_2 pneumoperitoneum and positional change are known to alter respiratory mechanics during general anaesthesia. Evaluating early changes in end-tidal CO_2 following positional change is important for guiding safe intraoperative ventilatory management during robotic surgeries.

Aims and objectives: This prospective observational study aims to compare mean end-tidal CO_2 ($EtCO_2$) values between the neutral supine position and 30° steep Trendelenburg position during pneumoperitoneum in robotic-assisted laparoscopic surgeries. The secondary objectives were to assess changes in Minute ventilation required to maintain normocapnia in neutral and 30° steep Trendelenburg positions, and to compare the Peak Airway pressures between the two positions.

Materials and Methods: Patients undergoing robot-assisted laparoscopic surgery were selected. Subjects were divided into two groups based on their position the Neutral group and the Steep Trendelenburg group. EtCO2 in neutral position and steep Trendelenburg position after insuflation of gas is measured at 10 min, 20 min, 30 min and other respiratory parameters like minute ventilation and peak airway pressures were also monitored.

Result: There was a significant increase in ($EtCO_2$) levels in the steep Trendelenburg position. Specifically, at the 30-minute mark, the mean $EtCO_2$ was 38.85 ± 2.15 mmHg in the Trendelenburg position compared to 33.95 ± 2.79 mmHg in the neutral position. As a secondary outcome, there was a compensatory rise in both Minute Ventilation 40% (mean difference of 2.77 L/min) and Peak airway pressures in the Trendelenburg position, showing a mean difference of 8.65 cmH_2O. Data analysed using paired t-test.

Conclusion: This study concludes that steep Trendelenburg positioning significantly elevates end-tidal CO_2 and peak airway pressures, creating a challenging respiratory environment that necessitates increased minute ventilation in robotic-assisted laparoscopic surgeries.

Keywords: Robotic-assisted laparoscopic surgeries,

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INTRODUCTION

While robotic-assisted laparoscopic surgery (RALS) offers significant surgical advantages, it presents unique anaesthetic challenges driven by the necessary creation of CO_2 pneumoperitoneum, which leads to systemic CO_2 absorption and increased intra-abdominal pressure[1,2]. These physiological disturbances are significantly exacerbated by the steep Trendelenburg position often required for surgical exposure, which further compromises respiratory mechanics by displacing the diaphragm cephalad and reducing functional residual capacity[3]. Maintaining intraoperative normocarbia, monitored via end-tidal CO_2 ($EtCO_2$), becomes progressively more difficult as the duration of the surgery increases and these physiological stressors compound over time [4]. Although the acute ventilatory effects of positioning are known, there is limited data regarding the longitudinal trajectory of $EtCO_2$ during *prolonged* exposure to these varying positions [5]. Therefore, the objective of this study is to compare the impact of neutral versus steep Trendelenburg positioning on the trends of $EtCO_2$ during prolonged CO_2 pneumoperitoneum in robotic-assisted surgeries**.**

METHODOLOGY

Ethical approval for this prospective observational study was obtained from the Institutional Review Board (IRB) at Saveeetha University, SIMATS, Chennai. Written informed consent was obtained from all the participants. This study was done from June 2024 to December 2024 at Saveetha Medical College and Hospital (SMCH). Patients aged 18 or above and less than 60, with ASA classification 1 to 2, who were scheduled for elective robotic-assisted laparoscopic surgeries. Inclusion criteria include patients who are aged between 18 and 60 years who undergo robotic laparoscopic surgeries requiring Trendelenburg positioning. Exclusion criteria include patient refusal, COPD patients, and morbidly obese patients.

Demographic data, including age, weight, and height, were recorded for all patients. The patients are then taken to the operating theatre, and standard monitors are connected. (pulse rate, NIBP, SPO2, electrocardiography), and pre-anaesthetic values are recorded. Peripheral venous access was obtained, and IV fluids were administered. After adequate preoxygenation, patients in both groups were induced with Inj Fentanyl 2mcg/kg iv, Inj Propofol 2mg/kg iv and muscle relaxant Inj Vecuronium 0.1mg/kg iv is given. Anaesthetic plane was maintained with O2: N2O-1:1, Isoflurane- 1.5% and intermittent boluses of Vecuronium. Patients were ventilated in volume-controlled mode with tidal volume: 6–8 mL/kg predicted body weight, I:E ratio: 1:2, PEEP: 5 cmH_2O, FiO_2 adjusted to maintain SpO_2 98-100%. Respiratory rate was adjusted to maintain end-tidal CO_2 ($EtCO_2$) between 35–45 mmHg. In the mechanical ventilator used, Peak airway pressures were continuously measured automatically by the ventilator in VCV mode as the inspiratory pause time was set to the default of 5%. Patients were positioned initially in a neutral supine position. Pneumoperitoneum was achieved with an intraperitoneal pressure of 10-12 mmHg.

End-tidal carbon dioxide ($EtCO_2$) values were recorded at predefined time intervals. Baseline $EtCO_2$ was measured after tracheal intubation and before creation of pneumoperitoneum. Following pneumoperitoneum, $EtCO_2$ was recorded in the supine position at 10, 20, and 30 minutes. Subsequently, after positioning the patient in a 25–30° Trendelenburg position, $EtCO_2$ measurements were obtained at 10, 20, and 30 minutes. Minute ventilation and peak airway pressures were also recorded at 10, 20, and 30 minutes in both the neutral supine position and the 25–30° Trendelenburg position. The primary outcome is the impact of Trendelenburg positioning and pneumoperitoneum on EtCo2 at given intervals, while the secondary outcome is their effect on respiratory mechanics.

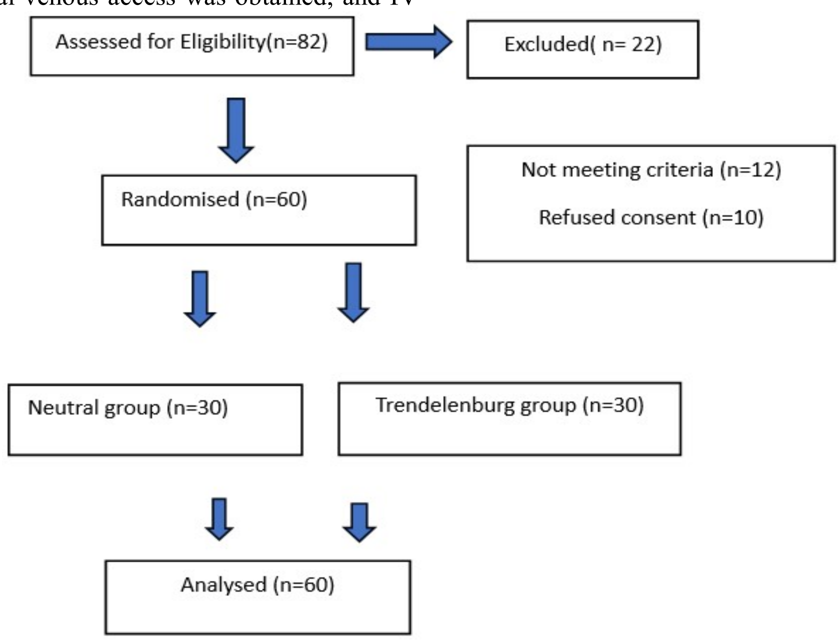


Figure 1: CONSORT flow diagram showing enrolment, allocation and analysis of the participants

Sample size calculation: Sample size estimation was based on previous studies reporting a mean increase in end-tidal CO_2 of approximately 4–6 mmHg with a standard deviation of about 5 mmHg during robotic-assisted laparoscopic surgeries in a steep Trendelenburg position. Using these values, a paired comparison with 95% confidence and 80% power required a minimum of 52 patients. To account for possible dropouts and incomplete data, 80 patients were initially enrolled; however, 60 patients were finally analysed, which exceeded the minimum required sample size and ensured adequate statistical power.

Statistical analysis:

Demographic data were expressed as mean ± standard deviation (SD) for continuous variables and as frequencies and percentages for categorical variables. Baseline end-tidal CO_2 ($EtCO_2$) values before intubation were recorded and analysed descriptively. $EtCO_2$ values following pneumoperitoneum at 10, 20, and 30 minutes in the neutral supine position and 25° Trendelenburg position were compared using a paired t-test for normally distributed data or a Wilcoxon signed-rank test for non-normal data. Changes in minute ventilation and peak airway pressures at 10, 20, and 30 minutes between the two positions were analysed similarly using paired statistical tests. For comparison of trends over time within each position, repeated-measures ANOVA or the Friedman test was applied as appropriate. A p-value <0.05 was considered statistically significant.

RESULTS

Table 1. Baseline Demographic and Clinical Characteristics of Study Population

Parameter	**values**
Age (years),mean SD	48.6 ± 9.2
Sex (Male/Female),n (%)	26 (43.3%) / 3(56.7%)
Body Mass Index (kg/m²) , mean ± SD	26.4 ± 3.6
ASA ,n (%)	ASA I: 28 (46.7%) ASA II: 32 (53.3%)
Type of Surgery, n (%)	Robotic-assisted laparoscopic hysterectomy (60%) Radical prostatectomy (40%)
Intra-abdominal pressure (mmHg), mean ± SD	12.8 ± 1.0
Trendelenburg angle (degrees)	25°
Duration of pneumoperitoneum (minutes), mean ± SD	72 ± 18
Baseline $EtCO_2$ after intubation (mmHg), mean ± SD	38.5 ± 2.1

Baseline minute ventilation after intubation (L/min), mean ± SD	6.6 ± 0.8
Baseline peak airway pressure after intubation (cmH_2O), mean ± SD	18.9 ± 2.6

Baseline demographic, surgical, and anaesthetic characteristics of the 60 patients are presented in Table 1. All patients were ASA physical status I or II and underwent robotic-assisted laparoscopic cholecystectomy. Baseline ventilatory parameters, including minute ventilation and peak airway pressure after intubation, were recorded prior to positional change.

Primary Outcome: The primary outcome of this study is compared in Table 2. The EtCO2 concentrations between the neutral (Supine) position and the 30-degree Trendelenburg position during pneumoperitoneum were analysed at 10, 20, and 30-minute intervals. A paired t-test was performed to analyse the difference in mean EtCO2 values between the two positions. The analysis revealed a statistically significant increase in EtCO2 levels in the Trendelenburg position compared to the Supine position at all measured time points ($p < 0.001$).

Table 2: Comparison of Mean EtCO2 (mmHg) in Supine vs. Trendelenburg Position (n=60)

Time Interval	**Neutral Position (Mean ± SD)**	**Trendelenburg Position (Mean ± SD)**	**Mean Difference**	**P-Value**
10 Min	30.37 ± 2.41	35.85 ± 2.65	5.48	< 0.001*
20 Min	31.12 ± 2.02	37.67 ± 2.29	6.55	< 0.001*
30 Min	33.95 ± 2.79	38.85 ± 2.15	4.90	< 0.001*

Values are expressed as Mean ± SD with triplicates. P – values are exposed the statistically significant range difference between the **Mean EtCO2 (mmHg) in Supine vs. Trendelenburg Position** at 0.001% levels followed by paired t-test.

Secondary outcome:

The secondary outcome is compared in Tables 3 and 4. In Table 3, minute ventilation is compared. The data demonstrates that maintaining end-tidal CO2 within normal limits during the Trendelenburg position requires a progressive and substantial increase in minute ventilation (approximately a 40% increase by 30 minutes).

Figure 2: Trend of EtCo2 Over Time

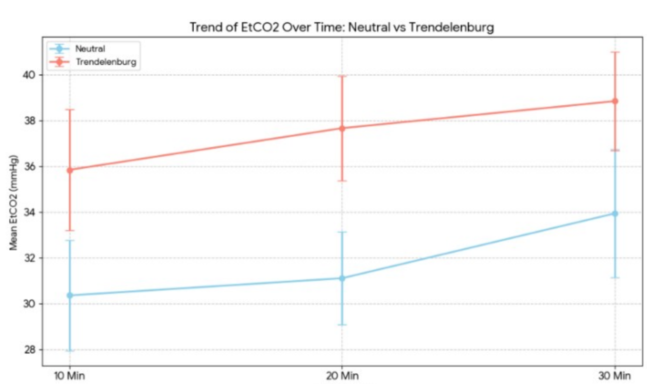
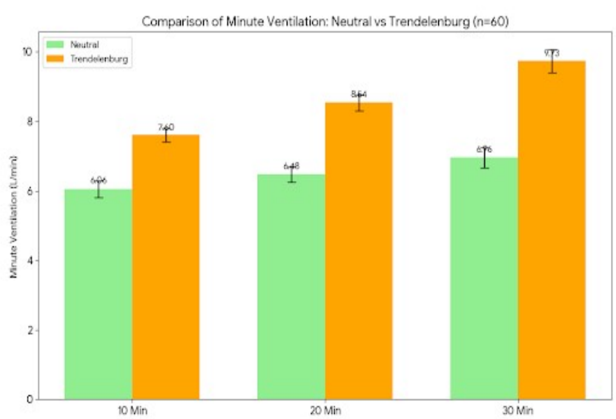


Table 3: Comparison of Minute Ventilation (L/min)

Time Interval	Neutral Position (Mean ± SD)	Trendelenburg Position (Mean ± SD)	Mean Difference	P-Value
10 Min	6.06 ± 0.24	7.61 ± 0.19	1.55	< 0.001*
20 Min	6.48 ± 0.22	8.54 ± 0.23	2.06	< 0.001*
30 Min	6.96 ± 0.29	9.73 ± 0.34	2.77	< 0.001

Values are expressed as Mean ± SD with triplicates. P – values exhibited the statistically significant range at 0.001% levels followed by paired t-test.

As a part of the secondary outcome, peak pressures are also compared in Table 4. The study demonstrated a highly significant elevation in airway pressures in the Trendelenburg position compared to the Neutral position across all time points ($p < 0.001$). The mean difference is roughly 8.65 cmH2O at 30 minutes.



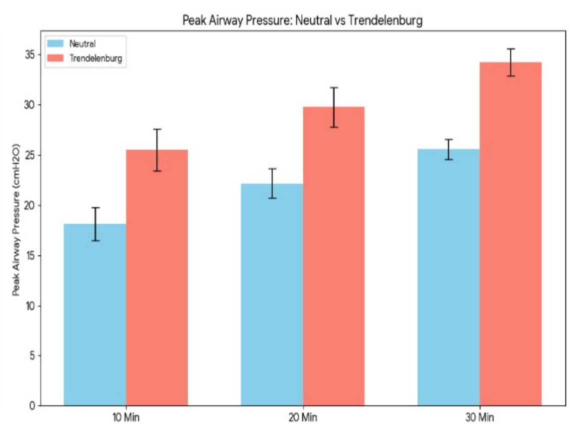


Figure 3: changes in respiratory parameters in both positions at various time intervals.

In Figure 3, together, these graphs depict a "double hit" to the respiratory system: the Trendelenburg position simultaneously increases airway resistance while demanding higher ventilation volumes, creating a challenging scenario for mechanical ventilation.

Table 4: Peak Airway Pressure Analysis

Time Interval	Neutral Position (Mean ± SD)	Trendelenburg Position (Mean ± SD)	Mean Difference (cmH2O)	t-value	P-Value
10 Min	18.15 ± 1.66	25.52 ± 2.07	7.37	-22.39	< 0.001*
20 Min	22.17 ± 1.46	29.77 ± 1.97	7.60	-24.12	< 0.001*
30 Min	25.57 ± 1.01	34.22 ± 1.35	8.65	-40.67	< 0.001

Values are expressed as Mean ± SD with triplicates. P – values presented the statistically significant range at 0.001% levels followed by paired t-test.

DISCUSSION

The present study demonstrates that the steep Trendelenburg (ST) position (30°) combined with CO_2 pneumoperitoneum significantly alters respiratory physiology compared to the neutral supine position[12, 13]. Our results showed a progressive and statistically significant increase in End-Tidal CO_2 ($EtCO_2$), Peak Airway Pressures (Peak), and the Minute Ventilation (MV) required to maintain normocapnia across all time intervals (10, 20, and 30 minutes).

These findings align with the physiological challenges described by Gainsburg, 2012[1], who noted that robotic-assisted laparoscopic surgeries [12] present unique anaesthetic concerns due to the systemic absorption of CO_2 and increased intra-abdominal pressure.

Our observation of a mean increase in $EtCO_2$ of approximately 5–6 mmHg in the ST group supports the work of Kalmar *et al.* (2010)[3] who reported significant disturbances in respiratory homeostasis during robotic prostatectomies due to the combined effects of positioning and pneumoperitoneum. While Kalmar *et al.* (2010)[3] focused on prolonged homeostasis, our study quantifies the acute "double hit" to the respiratory system within the first 30 minutes, necessitating a rapid ventilatory response.

Regarding respiratory mechanics, we observed a substantial rise in Peak Airway Pressures, with a mean difference of 8.65 cm H_2O at 30 minutes compared to the neutral position. This is consistent with the pulmonary mechanics described by Fahy and Barnas (2000)[4] and Popescu *et al.*2023[6], who attribute reduced lung compliance to the cephalad displacement of the diaphragm and the weight of abdominal viscera compressing the lung bases.

Furthermore, our study found that maintaining $EtCO_2$ within normal limits required a 40% increase in minute ventilation by the 30-minute mark. This validates the ventilatory management strategies suggested by Mulier (2010)[2], emphasising that standard ventilation settings are often insufficient to counteract the hypercarbic burden imposed by CO_2 insufflation and steep positioning. Unlike Seyit *et al.,(*2025)[8] who compared reverse Trendelenburg positions, our data specifically highlights the burden of the steep Trendelenburg position, confirming it as a distinct high-risk period for respiratory compromise.

CONCLUSION

In conclusion, this study confirms that the steep Trendelenburg position (30°) during robotic-assisted laparoscopic surgeries significantly compromises respiratory dynamics compared to the neutral position. The combination of pneumoperitoneum and steep positioning results in a marked elevation in end-tidal carbon dioxide levels and peak airway pressures, necessitating a substantial increase in minute ventilation to maintain normocapnia. These findings underscore the importance of proactive ventilatory management and vigilant monitoring by the anaesthesiologist to mitigate the physiological stress imposed by this surgical positioning.

Limitations

The limitations of this study include its single-centre design and the restriction of the study population to patients with ASA physical status I and II, which limits the generalizability of the findings to patients with significant comorbidities such as morbid obesity or chronic obstructive pulmonary disease (COPD). Additionally, the study relied on End-Tidal CO_2 ($EtCO_2$) as a surrogate for arterial partial pressure of carbon dioxide ($PaCO_2$) without concurrent arterial blood gas (ABG) analysis; while $EtCO_2$ is a standard non-invasive monitor, the arterial-to-end-tidal CO_2 gradient can fluctuate during pneumoperitoneum. Finally, the analysis was limited to the first 30 minutes of positioning, and further research would be beneficial to assess whether these respiratory parameters stabilize or deteriorate further during more prolonged surgical durations.

Conflict of Interest: Nil

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REFERENCES

1. Gainsburg, D. M. (2012). Anaesthetic concerns for robotic-assisted laparoscopic radical prostatectomy. *Minerva Anestesiologica*, *78*(5), 596-604.

2. Mulier, J. P. (2010). Ventilatory management during pneumoperitoneum and laparoscopic surgery. *Open Anesthesiology Journal*, *4*, 49-58.

3. Kalmar AF, Dewaele F, Foubert L, et al. Cerebral haemodynamic physiology during steep Trendelenburg position and CO_2 pneumoperitoneum. *British Journal of Anaesthesia*. 2012;108(3):478–484. doi:10.1093/bja/aer448.

4. Fahy, B. G., & Barnas, G. M. (2000). Pulmonary mechanics during laparoscopic surgery. *Seminars in Laparoscopic Surgery*, *7*(3), 144-152.

5. Sharma, K. C., et al. (1996). Cardiopulmonary physiology and pathophysiology as a consequence of laparoscopic surgery. *Chest*, *110*(3), 810-815

6. Popescu M, Olita MR, Stefan MO, Mihaila M, Sima RM, Tomescu D. Lung mechanics during video-assisted abdominal surgery in Trendelenburg position: a cross-sectional propensity-matched comparison between classic laparoscopy and robotic-assisted surgery. J Clin Monit Comput. 2023;37(4):915-924.

7. Saghana MS, Jothika J, Balamurugan B, Rajkumar RHB. Comparative analysis of end tidal carbon dioxide ($EtCO_2$) before pneumoperitoneum, immediately after pneumoperitoneum and 10 minutes after pneumoperitoneum during laparoscopic

surgeries. *Eur J Cardiovasc Med.* 2024;14(5):440–444.

8. Seyit H, Dolğun I, Bayram E, Şener FN, Çiçek M. The effect of two different surgical positions on pulmonary functions in laparoscopic sleeve gastrectomies: reverse Trendelenburg vs beach chair. Surg Endosc. 2025;39(3):1829–1838. doi:10.1007/s00464-025-11538-2.

9. Xue S, Wang D, Tu HQ, Gu XP, Ma ZL, Liu Y, Zhang W. The effects of robot-assisted laparoscopic surgery with Trendelenburg position on short-term postoperative respiratory diaphragmatic function. *BMC Anesthesiol.* 2024;24:92. doi:10.1186/s12871-024-02463-3.

10. Tontu F, Akca H, Berktas CK, Asar S, Ozcan FG. The impact of pneumoperitoneum and steep Trendelenburg positioning on novel oxygenation and saturation indices in robot-assisted laparoscopic prostatectomies: A prospective observational study. Saudi J Anaesth 2025;19:271-6.

11. Miller RD, Cohen NH, Eriksson LI, Fleisher LA, Wiener-Kronish JP, Young WL, editors. *Miller's Anesthesia*. 9th ed. Philadelphia: Elsevier; 2020. Chapter: Anesthesia for Laparoscopic and Robotic Surgery.

12. Choi DK, Lee IG, Hwang JH. Arterial to end-tidal carbon dioxide pressure gradient increases with age in the steep Trendelenburg position with pneumoperitoneum. *Korean Journal of Anesthesiology*. 2012;63(3):209–215.

13. Barud M, Turek B, Dąbrowski W, Siwicka D. Anesthesia for robot-assisted surgery: a review. *Anaesthesiology Intensive Therapy*. 2025. doi:10.5114/ait/203168