Comparison of arterial to end-tidal carbon dioxide gradient $P(a-ET)CO_2$ in volume versus pressure controlled ventilation in patients undergoing robotic abdominal surgery in the Trendelenburg position. A randomised controlled study

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ABSTRACT

Background and Aims: Robotic surgery is increasingly prevalent as an advancement in care. Steep head-down positions in pelvic surgery can increase the ventilation-perfusion mismatch and increase ventilatory requirements to offset carbon dioxide (CO$_2$) increases consequent to pneumoperitoneum. The primary objective was to assess the impact of two ventilatory strategies, volume versus pressure-controlled ventilation on the arterial to end-tidal carbon dioxide gradient $P(a-ET)CO_2$ in patients undergoing robotic surgery in the Trendelenburg position. The effects on alveolar to arterial oxygen gradient $P(A-a)O_2$, peak airway pressure ($P_{aw}$), dynamic compliance ($C_{dyn}$) and haemodynamics were also assessed. Methods: Fifty-one patients, 18-75 y, American Society of Anesthesiologists I-III undergoing robotic surgery in Trendelenburg position were randomised to volume-controlled ventilation (Group VCV) or pressure-controlled ventilation (Group PCV). The $P(a-ET)CO_2$ was measured at baseline T0, 10 min after Trendelenburg position T1, 2 h of surgery T2, 4 h T3 and at T$e$, 10 min after deflation. The $P_{aw}$, $C_{dyn}$, heart rate and blood pressure were also measured at the same time. Results: The $P(a-ET)CO_2$ at T1, T2, T3 and at T$e$ was lower in Group PCV versus Group VCV. The $P_{aw}$ was lower at T1, T2, and T3 and $C_{dyn}$ higher at T3 and T$e$ in Group PCV at comparable minute ventilation. Haemodynamics and $P(A-a)O_2$ were comparable between the groups. Conclusion: Pressure-controlled ventilation reduces $P(a-ET)CO_2$ gradient, $P_{aw}$ and improves $C_{dyn}$ but does not affect $P(A-a)O_2$ or haemodynamics in comparison to volume-controlled ventilation in robotic surgeries in the Trendelenburg position.

Key words: Carbon-dioxide, head down tilt, robotic surgical procedures
absorption of carbon-dioxide (CO₂) during the creation of pneumoperitoneum increases arterial carbon dioxide (PaCO₂). The increase in airway pressures and rise in PaCO₂ with pneumoperitoneum warrant adjustments to maintain an appropriate ETCO₂.

The lack of accuracy of ETCO₂ in predicting PaCO₂ has been reported in laparoscopic colorectal surgery and amongst the elderly. Pressure-controlled ventilation (PCV) is considered a superior ventilatory mode as its decelerating flow reduces airway pressures in comparison to volume-controlled ventilation (VCV).

The primary objective was to assess the impact of two different ventilatory modes, PCV and VCV on P (a-ET) CO₂ during robotic surgery in the head-down position.

The secondary objectives included comparison of peak airway pressure (Pₐₐₚ), dynamic compliance (Cdyn), alveolar to arterial oxygen gradient (P (A-a)O₂) and haemodynamics between the two groups.

**METHODS**

Following approval from the institutional Ethics Committee and registration with the Clinical Trials Registry of India (CTRI/2019/03/018312), a prospective randomised study was conducted at the gastro-surgery, urology and gynaec-oncology divisions of a tertiary care referral hospital between April 2019 and October 2020.

Patients scheduled for robotic pelvic surgery were screened and consenting patients belonging to American Society of Anesthesiologists physical status I, II and III between the age group of 18-75 years undergoing elective abdominal and pelvic robotic surgery in the Trendelenburg position were included.

Exclusion criteria were body mass index >35, chronic smokers, documented chronic obstructive pulmonary disease, increased pulmonary artery pressures on echocardiography, poor cardiac reserve, asthma or other chronic lung diseases.

All patients were pre-medicated as per institutional protocol with oral alprazolam 0.25 mg, pantoprazole 40 mg and oral metoclopramide 10 mg on the night before and on the morning of surgery as per the policy of the surgical unit.

Patients were shifted to the operating room, and after placement of monitors, an intravenous line and a radial arterial line were inserted under local anaesthesia. The baseline heart rate and blood pressure were recorded and room air arterial blood gas was obtained. All patients received general anaesthesia as per a standardised protocol with intravenous midazolam 0.05 mg/kg, fentanyl 2 µg/kg, propofol titrated to loss of verbal response and intubation with atracurium at 0.5 mg/kg or rocuronium (0.9 mg/kg). Low flow anaesthesia with 1.0 L air oxygen mixture (50% oxygen) and sevoflurane at 0.7-1.0 minimum alveolar concentration was used.

All patients were initially ventilated in the VCV mode with the tidal volume of 7 ml/kg predicted body weight (PBW), inspiratory: expiratory (I: E) ratio 1:2, positive end expiratory pressure (PEEP) of 5 cm of H₂O and fractional inspired concentration of oxygen (FiO₂) 0.5. The PBW was calculated by the formula: PBW kg = 50 + 0.91{Height cm − 152.4} in men and 45 + 0.91{Height (cm) − 152.4} in women. The respiratory rate was adjusted to maintain an ETCO₂ of 35 – 45 mm Hg using Dräger Perseus A 500 workstation with a side-stream capnometer and I: E ratio constant at 1:2. The apparatus dead space between the Y connection of the circle system and the tip of the tracheal tube was negligible. Heat and moisture exchange filters with 42 ml dead space each were used at the point of attachment of the endotracheal tube to the Y connector and at the machine end of the expiratory limb in all patients.

After marking the port sites and the creation of CO₂ pneumoperitoneum patients were placed in Trendelenburg position (30°) (Smart Tool factory app Angle meter). Intra-abdominal pressure was maintained below 12 mmHg during surgery with da Vinci robotic system.

Patients were randomised into either Group PCV or Group VCV by a computer-generated random number sequence of numbers and concealed allocation ensured by sequentially numbered opaque sealed envelopes. Readings were taken by the anaesthesiologist assigned to the operating room.

In Group PCV, the inspiratory pressure (Pi) cm H₂O was set to deliver a target tidal volume of 7 ml/kg PBW and the respiratory rate adjusted to maintain an ETCO₂ between 35 and 45 mmHg. If the ETCO₂ rose above 45 mm Hg, the respiratory rate was increased at 2 breaths every 2 minutes to a maximal rate of 25 breaths per minute. Simultaneously, the Pi was increased in increments of 2 cm H₂O until the target
ETCO₂ was achieved to maximal airway pressures not exceeding 35 cm H₂O.

In group VCV, tidal volume of 7 ml/kg PBW and respiratory rate adjusted to ETCO₂ of 35–45 mm Hg to a maximum rate of 25 breaths per minute was set. If the airway pressures increased above 35 cm H₂O, the tidal volume was reduced in decrements of 1 ml/kg every 2 minutes until the peak pressure was below 35 cm H₂O before increasing the rate further. If peak airway pressure exceeded 35 cm of H₂O and PaCO₂ exceeded 50 mm Hg, PEEP was decreased and the intraabdominal insufflation pressure was reduced to allow the PaCO₂ to normalise. If PaCO₂ continued to rise, then ventilatory mode was changed and the patient was excluded from the study.

A PEEP of 5 cm of H₂O was set in both groups. Haemodynamic management was as per standard protocols and noradrenaline infusion was begun if the mean arterial pressure was <65 mm Hg.

The alveolar dead space fraction (AVDSF) was calculated by the modified Bohr’s equation,[6]

\[
AVDSF = \frac{\text{PaCO}_2 - \text{ETCO}_2}{\text{PaCO}_2}
\]

The C_{O₂} (ml/cm H₂O) was obtained from the machine at the defined time points. The partial pressure of oxygen/fractional inspired oxygen concentration (PaO₂/FIO₂-P/F) ratio was obtained from the machine. The heart rate and blood pressure were noted from the arterial pressure readings at the set time points.

The rest of the anaesthetic management was as per standard protocols with air, oxygen, and sevoflurane. Ringer’s lactate was the fluid of choice and restrictive fluid strategy of 2 ml/kg/h was practised. Plasmalyte was added if measured lactate was ≥2 mmol/L. At the end of surgery, neuromuscular blockade was reversed and the trachea was extubated and all patients were shifted to the intensive care unit for postoperative care.

Blood gases were sampled at defined time points during surgery:
- **T0**: Baseline after intubation,
- **T1**: 10 minutes after the creation of pneumoperitoneum in Trendelenburg position,
- **T2**: 2 hours into the surgery,
- **T3**: 4 h of surgery and **Te**: 10 minutes after deflation of the pneumoperitoneum. The Pₐₕₑₑ', P (a-ET)CO₂ gradient and P (A-a) O₂ were also measured at the same time points.

The sample size was calculated from a pilot study of 20 patients with a comparison of P (a-ET) CO₂ gradient between PCV and VCV groups, (5.5 ± 1.0) and (7.4 ± 3.1) mm Hg at time point T2. With a 90% power and 95% confidence interval, the minimum sample size was determined to be 25 per group. To compare the mean difference of numerical variables between groups, an independent sample ‘t’ test was applied. To test the association of all categorical variables between the two groups, the Chi-square with Fisher’s exact test was applied. A P value of <0.05 was considered statistically significant. Statistical analysis was done using International Business Machines Corporation, Statistical Package for the Social Sciences (IBM SPSS) software 20.0 (SPSS Inc, Chicago, USA).

## RESULTS

A total of 51 patients were included for randomisation [Figure 1]. The demographics and duration of surgery were comparable between the groups [Table 1]. There were no drop outs after recruitment in the study. The baseline P (a-ET)CO₂ gradient was comparable between the groups. The mean P (a-ET) CO₂ gradients were significantly lower in group PCV at T1, T2, T3 and at Te when compared with group VCV, whereas the PaCO₂ was similar at all time points except at T3 when it was lower in the PCV group [Table 2]. The AVDSF was similar at baseline, T1, T2 but was higher in the VCV at 4 h into surgery and at 10 minutes after deflation [Table 2].

The C_{O₂} was higher in the PCV group at T3 and Te, whereas the Pₐₕₑₑ', was significantly lower at T1, T2 and T3 in comparison to the VCV group. The (A-a) DO₂ was comparable between both groups but the P/F ratio was higher in the VCV group at T1 [Table 3]. The minute ventilation in groups VCV and PCV at T0 (5.9 ± 0.9 versus 6.0 ± 0.9), T1 (6.1 ± 1.1 versus 6.4 ± 1.2), T2 (7.0 ± 1.1 versus 7.1 ± 0.9), T3 (7.3 ± 1.1 versus 7.2 ± 1.1) and Te (7.1 ± 1.5 versus 7.0 ± 1.5) was comparable, P > 0.05. The heart rate

### Table 1: Demographics and duration of surgery

|                  | VCV (n=25) | PCV (n=26) | P    |
|------------------|------------|------------|------|
| Age (years)      | 64±8.9     | 60.8±10.7  | 0.399|
| Height (cm)      | 163.0±2.1  | 165.0±1.6  | 0.505|
| Weight (kg)      | 67.7±2.4   | 69.2±1.6   | 0.608|
| BMI (kg/m²)      | 28.5±1.9   | 27.7±0.6   | 0.691|
| PBW (kg)         | 59.3±1.9   | 62.1±1.5   | 0.133|
| Duration (min)   | 233.0±65.8 | 255.0±65.1 | 0.221|

VCV: Volume controlled ventilation; PCV: Pressure controlled ventilation; SD: Standard deviation; BMI: Body mass index; PBW: Predicted body weight.
and blood pressure were also comparable between the groups [Figures 2 and 3].

**DISCUSSION**

Safety of using end-tidal CO$_2$ as a surrogate of arterial CO$_2$ and impact of ventilatory modes on the P (a-ET) CO$_2$ was compared in patients undergoing robotic surgeries in the Trendelenburg position. The P (a-ET) CO$_2$ gradient was significantly lower in the PCV group throughout the study even while the minute ventilation between both the groups was comparable. The AVDSF showed an increase at 4 hours after pneumoperitoneum and at 10 minutes after the release of pneumoperitoneum in the VCV group suggesting that PCV may reduce the dead space and improve ventilation. The $P_{aw}$ was also lower in the PCV group for the duration of the laparoscopy and $C_{dyn}$ improved at 4 hours and after deflation in the PCV group, highlighting that PCV could be a superior mode in this surgical group.

Laparoscopic surgery in the Trendelenburg position causes changes in respiratory mechanics during surgery. The primary objective of the study was to compare the relationship between P (a-ET) CO$_2$ between two ventilatory modes and ventilatory changes were made to ensure standardisation in management. The P (a-ET) CO$_2$ was higher in the VCV group for the same target of ETCO$_2$ with adjusted ventilation. The PaCO$_2$ during laparoscopic surgery is an end measure of minute ventilation and the corresponding ETCO$_2$ represents phase III of the capnograph.\[7\] In children, a negative gradient can occur at particular times such as deflation of pneumoperitoneum following laparoscopic surgery when excessive alveolar ventilation ensues with the sudden increase in lung compliance.
Although the impact of PCV versus VCV on other respiratory variables has been extensively studied,[8,9] little is known of the impact on alveolar ventilation and thereby $P_{(a-ET)}CO_2$. PCV is a time-cycled mode with decelerating flow and a square wave pattern of ventilation that can provide effective alveolar ventilation which explain our findings. Increasing age has been shown to increase the $P_{(a-ET)}CO_2$ in the supine position but in our study, the groups were comparable in age.[10] In a study of respiratory variables in robotic prostatectomy, PCV showed a decrease in $P_{(a-ET)}CO_2$ gradient in comparison to the VCV group after pneumoperitoneum.[11] A study in laparoscopic colonic surgery[3] concluded that there was no reliable correlation between $P_{(a-ET)}CO_2$ amongst forty patients using uniform ventilatory strategies. This is contrary to a study comparing the $P_{(a-ET)}CO_2$ in laparoscopic nephrectomy where the authors could establish a trend between end-tidal $CO_2$ and $PaCO_2$.[12]

Several studies have shown that PCV improved lung compliance and oxygenation in comparison to VCV.[13-18] An additional finding in the colorectal study was an increase in the inflammatory markers sRAGE and S100A12 leading to a higher incidence of postoperative complications.[18] We did not follow the outcomes of the patients in the intensive care unit and this may have led to more insights into the impact of ventilatory strategies.

The study amongst colorectal patients[3] suggested that the differences could increase with a duration of laparoscopy beyond 250 minutes but confounding influences of hypoxic pulmonary vasoconstrictive responses to inhalational agents and alterations of dead space to tidal volume ratios could affect the relationship.

Studies show that the haemodynamic and pulmonary parameters remained within normal limits during the surgery indicating that the Trendelenburg position and $CO_2$ pneumoperitoneum are well tolerated.[14,17] Haemodynamic changes that occur with pneumoperitoneum include an increase in systemic

| Time | Group VCV | Group PCV | $P$ |
|------|-----------|-----------|-----|
|      | Mean±SD   | Mean±SD   |     |
| T0   | 36.4±14.0 | 34.2±9.9  | 0.503 |
| T1   | 21.5±6.4  | 20.3±5.3  | 0.467 |
| T2   | 18.4±4.9  | 17.1±2.7  | 0.395 |
| T3   | 16.6±4.6  | 22.7±5.9  | 0.011 |
| Te   | 30.1±5.5  | 35.4±7.01 | 0.005 |

C$_{dyn}$: Dynamic compliance. (A-a) $DO_2$: Alveolar to arterial oxygen gradient. $P_{aw}$: Peak airway pressure. P/F: $PaO_2$/FiO$_2$. SD: Standard deviation

Figure 3: Blood pressure between groups PCV and VCV

Table 3: Respiratory variables between Group VCV versus Group PCV

| Time | Group VCV | Group PCV | $P$ |
|------|-----------|-----------|-----|
|      | Mean±SD   | Mean±SD   |     |
| T0   | 16.4±2.1  | 18.1±4.3  | 0.068 |
| T1   | 28.1±3.7  | 26.0±3.4  | 0.043 |
| T2   | 30.4±3.2  | 26.1±4.1  | <0.001 |
| T3   | 30.5±2.8  | 26.1±2.8  | 0.001 |
| Te   | 19.3±2.8  | 18.9±2.7  | 0.607 |

| Time | Group VCV | Group PCV | $P$ |
|------|-----------|-----------|-----|
|      | Mean±SD   | Mean±SD   |     |
| T0   | 111.8±25.6| 111.0±21.8| 0.903 |
| T1   | 149.6±35.9| 167±33.0  | 0.068 |
| T2   | 165.9±29.7| 174.6±22.1| 0.259 |
| T3   | 166.9±35.0| 169.3±29.0| 0.862 |
| Te   | 159.3±30.0| 162.7±28.5| 0.677 |

$P_{aw}$ cmH$_2$O: Peak airway pressure. P/F: $PaO_2$/FiO$_2$. SD: Standard deviation
vascular resistance, a decrease in cardiac output and an increase in pulmonary artery pressures and wedge pressures. As patients with compromised cardiac status were not included, we did not encounter cardiovascular instability in our study group. Our observations with haemodynamic parameters showed comparable changes between the two groups. An evaluation of respiratory variables and supportive haemodynamic monitoring on transitioning from VCV to PCV during urologic laparoscopy showed that PCV improved inspiratory flow, dynamic compliance and reduced airway pressures without affecting cardiac function.

Although few have reported facial puffiness at the end of surgery, Trendelenburg position has been tolerated even in obese patients undergoing robotic gynaecological surgery without any overt evidence of increased intracranial pressure. Restrictive fluid strategies are shown to be safe and do not affect lactates or renal function in colorectal surgery. The role of the endothelial glycocalyx in maintaining vascular integrity has been increasingly recognised and conservative fluids help in its preservation. We did not encounter facial puffiness perhaps with a combination of minimal head down, exclusion of obese patients, use of restrictive fluids, management of peak airway and intra-abdominal pressures.

Most studies evaluating PCV versus VCV during surgery have documented improved oxygenation in the PCV group. PCV has a decelerating flow that opens the alveoli early during inspiration and minimises the pressure difference between the conducting airway and alveoli. The subsequent decelerating flow maintains the alveoli open, preventing their collapse. Nevertheless, the PCV group in our study did not have an improvement in P/F ratio which was higher at T1 in the VCV group.

Our results suggest that the use of PCV amongst patients undergoing laparoscopic robotic surgery in the Trendelenburg position can provide better alveolar ventilation, more accurate representation of PaCO₂, improved Cdyn and Paw with its decelerating flow and square pattern. The reduction in AVDSF could perhaps contribute to the reduced P (a-ET) CO₂. There were no haemodynamic differences between the ventilatory modes and the Trendelenburg position was well tolerated in both modes.

There were limitations in our study. The readings for comparison were taken at specified time points. Variations in Paw and intra-abdominal pressures with surgical movements could have occurred at some measurement points. The plateau pressure was not included during measurement and only the peak airway pressure between the modes was compared. Baseline differences in pulmonary function amongst the elderly could have introduced some differences in our readings. Due to constraints in surgical numbers during the pandemic, we included all robotic surgeries in Trendelenburg including gynaecological, urological and gastrointestinal surgery to obtain adequate sample size. This resulted in heterogeneity amongst surgical types. Variations in pulmonary blood flow and use of PEEP could have affected the alveolar dead space. For the safety of patients, the methodology involved an adjustment of ventilation to maintain the ETCO₂ in the desired range during this surgery. This may have contributed to variations in the P (a-ET) CO₂ during measurement.

A prospective study comparing a dual ventilatory mode versus VCV in a homogenous surgical group and cross over from one mode to the other in the same patient may provide insights into ventilatory changes in robotic surgery.

CONCLUSION

PCV reduces P (a-ET)CO₂ gradient throughout surgery, reduces the Paw and improves Cdyn but does not affect P (A-a)O₂ or haemodynamics in comparison to VCV in laparoscopic assisted robotic surgery in the Trendelenburg position.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Arvizo C, Mehta. ST, Yunker A. Adverse events related to Trendelenburg position during laparoscopic surgery. Curr Opin Obstetr Gynecol 2018:30:272-8.  
2. Hayden P, Cowman S. Anaesthesia for laparoscopic surgery.
Continuing Education in Anaesthesia Critical Care and Pain 2011;5:177-80.

3. Klopfenstein CE, Schiffer E, Pastor CM, Beausissier M, Francis K, Soravia C, et al. Laparoscopic colon surgery: unreliability of end-tidal carbon dioxide monitoring. Acta Anaesthesiol Scand 2008;52:700-7.

4. 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 J Anaesthesiol 2012;63:209-15.

5. Cadi P, Guenoun T, Journois D, Chevallier JM, Diehl JL, Saran D. Pressure controlled ventilation improves oxygenation during laparoscopic obesity surgery compared with volume-controlled ventilation. Br J Anaesth 2008;100:709-16.

6. Bhalla AK, Rubin S, Newth CJ, Ross P, Morzov R, Soto-Campos G, et al. Monitoring dead space in mechanically ventilated children. Volumetric capnography versus time-based capnography. Respir Care 2015;60:1548-55.

7. Shankar KB, Moseley H, Kumar Y. Negative arterial to end—tidal gradients. Can J Anaesth 1991;38:260-1.

8. Campbell RS, Davis BR. Pressure-controlled versus volume-controlled ventilation: Does it matter? Respir Care 2002;47:416-24.

9. Tyagi A, Kumar R, Sethi AK, Mohta M. A comparison of pressure-controlled and volume-controlled ventilation for laparoscopic cholecystectomy. Anaesthesia 2011;66:503–8.

10. Satoh K, Ohashi A, Kumagai M, Sato M, Kuji A, Joh S. Evaluation of differences between PaCO$_2$ and ETCO$_2$ by age as measured during general anaesthesia with patients in a supine position. J Anesthesiol 2015;Article ID: 710537. doi: 10.1155/2015/710537.

11. Jaju R, Jaju PB, Dubey M, Mohammad S, Bhargava AK. Comparison of volume-controlled ventilation and pressure-controlled ventilation in patients undergoing robot-assisted pelvic surgeries: An open-label trial. Indian J Anaesth 2017;61:17–23.

12. Jayan N, Jacob JS, Mathew M. Anaesthesia for laparoscopic nephrectomy: Does end-tidal carbon dioxide measurement correlate with arterial carbon dioxide measurement? Indian J Anaesth 2018;62:298-302.

13. Brandão JC, Lessa MA, Motta-Ribeiro G, Hashimoto S, Paula LF, Torsani V, et al. Global and regional respiratory mechanics during robotic-assisted laparoscopic surgery. Anesth Analg 2019;129:1564–73.

14. Meiningder G, Zwissler B, Byhahn C, Probst M, Westphal K, Bremerich DH. Impact of overweight and pneumoperitoneum on hemodynamics and oxygenation during prolonged laparoscopic surgery. World J Surg 2006;30:520–6.

15. Lebowitz P, Yedlin A, Hakimi AA, Bryan Brown C, Richards M, Ghavamian R. Respiratory gas exchange during robotic-assisted laparoscopic radical prostatectomy. J Clin Anesth 2015;27:470-5.

16. Assad OM, EL Sayed AA, Khalil MA. Comparison of volume-controlled ventilation and pressure controlled ventilation volume guaranteed during laparoscopic surgery in Trendelenburg position. J Clin Anesth 2016;34:55-61.

17. Kalmar AF, Foubert L, Hendrickx JF, Mottrie A, Absalom A, Mortier EP. Influence of steep Trendelenburg position and CO$_2$ pneumoperitoneum on cardiovascular, cerebrovascular, and respiratory homeostasis during robotic prostatectomy. Br J Anaesth 2010;104:433–9.

18. Choi S, Yang SY, Choi GJ, Kim BG, Kang H. Comparison of pressure and volume-controlled ventilation during laparoscopic colectomy in patients with colorectal cancer. Sci Rep 2019;9:17007.

19. Akinson TM, Giraud GD, Togioka BM, Jones DB, Cigarroa JE. Cardiovascular and ventilatory consequences of laparoscopic surgery. Circulation 2017;135:700-10.

20. Balick-Weber CC, Nicolas P, Hedreville-Montout M, Blanchet P, Stéphan F. Respiratory and haemodynamic effects of volume-controlled versus pressure-controlled ventilation during laparoscopy: A cross over study with echocardiographic assessment. Br J Anaesth 2007;99:429–35.

21. Sadashivaiah J, Ahmed D, Gul N. Anaesthetic management of robotic-assisted gynaecology surgery in the morbidly obese – A case series of 46 patients in a UK university teaching hospital. Indian J Anaesth 2018;62:443-8.

22. Kumar L, Kumar K, Sandhya S, Koshy DM, Ramamurthi KP, Rajan S. Effect of liberal versus restrictive fluid therapy on intraoperative lactate levels in robot-assisted colorectal surgery. Indian J Anaesth 2020;64:599-604.

23. Kundra P, Goswami S. Endothelial glycocalyx: Role in body fluid homeostasis and fluid management. Indian J Anaesth 2019;63:6-14.

24. Jiang J, Li B, Kang N, Wu A, Yue Y. Pressure-controlled versus volume-controlled ventilation for surgical patients: A systematic review and meta-analysis. J Cardiothorac Vasc Anesth 2016;30:501–14.