



Research Report

The effect of steep head-down tilt on respiratory status in endometrial cancer patients with obesity during robot-assisted hysterectomy

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ABSTRACT

Objective: To evaluate the effect of head-down tilt on airway pressure in gynecologic patients with obesity during robot-assisted hysterectomy.

Methods: We retrospectively reviewed the records of 27 patients with body mass index (BMI) ≥ 25 kg/m² who underwent robot-assisted hysterectomy for endometrial cancer and endometrial atypical hyperplasia using the da Vinci Xi system. Mechanical ventilation was performed using pressure-controlled ventilation (PCV). Surgery was performed at 20° (group A, n = 17) or 25° head-down tilt (group B, n = 10). Respiratory parameters, including positive end-expiratory pressure (PEEP), tidal volume (TV), mean airway pressure (P mean), and peak airway pressure (P peak), were measured before (T1) and after the head-down tilt at 1 h (T2) and 2 h (T3) during anesthesia.

Results: The median BMI was 37.5 (range 28–51) kg/m², with no between-group variation. Oxygenation was maintained intraoperatively for all patients. The expiratory carbon dioxide partial pressure was 43.6 (95% confidence interval (CI) 42.2–45.0) mmHg. The P mean peak at T2 in group B was significantly higher than in group A (P < 0.011); however, other parameters at T2 and T3 did not differ significantly between the groups. Patients with BMI ≥ 40 kg/m² had significantly higher respiratory parameters than those with BMI < 40 kg/m². In patients with BMI ≥ 40 kg/m², the mean P means and P peaks at T3 were 17.3 cmH₂O (95% CI 16.3–18.3) and 29.4 cmH₂O (95% CI 27.1–31.7), respectively.

Discussion: With careful anesthetic management during PCV, robot-assisted surgery with a head-down tilt of 25° or below may be safe, even in patients with class III obesity.

1. Introduction

Endometrial cancer is the most common malignancy associated with obesity, and approximately 57% of endometrial cancer cases in the United States are thought to be attributable to being overweight and obese (Calle and Kaaks, 2004; Renehan et al., 2008). Gynecologic surgeons are increasingly using minimally invasive surgery, particularly robot-assisted surgery, to perform hysterectomy to treat endometrial cancer (Cusimano et al., 2019; Sofer et al., 2020; Ran et al., 2014).

Robot-assisted laparoscopic gynecologic surgery is frequently performed in a steep Trendelenburg position for optimal surgical visualization. The 25–45° Trendelenburg position is strongly advocated because it provides better exposure of the operative field by displacing the bowels toward the upper abdomen. However, this negatively

impacts hemodynamics and pulmonary function by increasing the peak inspiratory pressure and decreasing dynamic lung compliance significantly when compared with the simple lithotomy position (Sprung et al., 2002). Steep Trendelenburg positioning results in increased peak and plateau airway pressures, particularly in patients with obesity, leading to concerns about the effects of steep Trendelenburg positioning on breathing in patients with class III obesity (body mass index [BMI] > 40 kg/m²) (Rouby et al., 2019).

It was hypothesized that in obese women, a steep head-down tilt might adversely affect respiratory parameters such as airway pressure. Therefore, the aim of this study was to evaluate the effect of steep head-down tilt on airway pressure in Japanese patients with obesity during robot-assisted laparoscopic hysterectomy.

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2. Patients and methods

This retrospective observational cohort study was approved by the Institutional Review Board of Chiba University (approval number 3719). We applied the opt-out method to obtain consent to extract patient data from digital medical records for this study.

The definition of obesity was adopted as a BMI $\geq 25 \text{ kg/m}^2$ from the definition in the Japan Society for the Study of Obesity (Examination Committee of Criteria for 'Obesity Disease' in Japan; Japan Society for the Study of Obesity, 2002). We retrospectively reviewed the records of 27 consecutive patients with a BMI $\geq 25 \text{ kg/m}^2$ who underwent robot-assisted hysterectomy for endometrial cancer (n = 22) and endometrial atypical hyperplasia (n = 5) using the da Vinci Xi system at Chiba University Hospital between January 2009 and December 2019. In our hospital, robotic surgery was indicated for patients estimated as stage IA, endometrioid grade 1 where pelvic lymph node dissection could be omitted. All patients, except two, underwent hysterectomy alone whereas pelvic lymph node sampling was performed in two cases. The surgery was performed with a head-down tilt of 20° before September 2019 (group A, n = 17) and 25° after September 2019 (group B, n = 10).

Pressure-controlled artificial ventilation with positive end-expiratory pressure (PEEP) was performed in all patients. Lung recruitment maneuvers were performed as deemed fit by the anesthesiologist. During surgery, pneumoperitoneum was established by the insufflation of carbon dioxide gas through periscopic insufflators, and an intra-abdominal pressure of $<10 \text{ mmHg}$ was maintained.

Respiratory parameters comprising PEEP, mean airway pressure (P mean), peak airway pressure (P peak), and tidal volume (TV) were measured prior to head-down tilt (T1) and at 60 min (T2) and 120 min (T3) after the establishment of the Trendelenburg position and pneumoperitoneum and compared between group A vs. B and BMI $< 40 \text{ vs. } \geq 40 \text{ kg/m}^2$.

The normal distribution of values was tested using the Kolmogorov–Smirnov test, and all data used for statistical analysis were normally distributed. Two independent group variables were compared using the Student's *t*-test. Data were expressed as means \pm 95% confidential interval. Statistical significance was set at a *P* value < 0.05 . All statistical analyses were performed using SPSS software version 20 (IBM-SPSS Corp., Armonk, NY, USA).

3. Results

The patient characteristics are shown in Table 1. No significant differences were found between group A and B in terms of age, BMI, total operative time, and total blood loss. Oxygenation was maintained in all patients during surgery. The expiratory carbon dioxide partial pressure was 43.6 (42.2–45.0) mmHg. In this study, no adverse effects occurred related to airway compromise. All the patients were extubated without incident postoperatively.

Table 1
Patient characteristics.

Characteristic	Total	Group A (20° head-down tilt)	Group B (25° head-down tilt)	<i>P</i>
	N = 27	N = 17	N = 10	
Age (years) ^a	46 (28–71)	48 (28–71)	40 (31–68)	N.S.
BMI (kg/m ²) ^a	37.5 (27.9–51.4)	37.3 (27.9–50.9)	38.9 (31.8–51.4)	N.S.
Operative time (min) ^b	228 (141–370)	232 (166–330)	221 (141–370)	N.S.
Total blood loss (ml) ^b	45 (10–225)	39 (10–225)	35 (10–150)	N.S.

BMI, body mass index; N.S., not significant.

^a median (range).

^b mean (range).

The mean PEEPs, P means, P peaks, and TVs did not differ significantly between group A and B (Table 2). However, the P peaks at T2 were 25.3 cmH₂O and 28.8 cmH₂O in group A and B, respectively, indicating significantly higher airway pressures in group B (*P* < 0.011). The increase in the P peak from T1 to T2 in group B was significantly higher than that in group A. The P means and P peaks of patients with BMIs ≥ 40 were significantly higher than those of patients with BMIs < 40 prior to head-down positioning (*P* < 0.004 and *P* < 0.004 , respectively). The TVs, P peaks, and P means of patients with BMIs ≥ 40 were significantly higher than those with BMIs < 40 after head-down tilt at T2 and T3 (Table 3).

In patients with BMI $\geq 40 \text{ kg/m}^2$, no significant differences in respiratory parameters were found between group A and B (Table 4). However, a head-down tilt of 25° resulted in a mean P peak of approximately 30 cmH₂O in patients with class III obesity (Table 4). We believe that a steep head-down tilt may be a risk factor for respiratory compromise in patients with class III obesity.

4. Discussion

Our data showed that Trendelenburg positioning of 20–25° during robot-assisted hysterectomy for endometrial cancer with CO₂ pneumoperitoneum may be safe in patients with obesity. However, the effect of this positioning on respiratory parameters is more significant in women with a BMI $\geq 40 \text{ kg/m}^2$ than in those with a BMIs $< 40 \text{ kg/m}^2$ and increased intra-respiratory pressure should be monitored carefully in women with a BMI $\geq 40 \text{ kg/m}^2$ at 25° of head-down tilt.

The combination of the Trendelenburg position and CO₂ pneumoperitoneum causes decreased lung compliance, increased P peaks, and atelectasis (Choi et al., 2008). A meta-analysis and several studies have shown that pressure-controlled ventilation (PCV) may be associated with better respiratory parameters, such as lower P peaks and airway resistance and higher lung compliance, in comparison to volume-controlled ventilation (Wang et al., 2015; Jaju et al., 2017; Lee et al., 2020). In the present study, under PCV anesthesia, a 5° difference in head-down tilt did not significantly impact respiratory status apart from the P peak.

We demonstrated that patients with a BMI $\geq 40 \text{ kg/m}^2$ had a marked increase in P means and P peaks compared with patients with a BMI $<$

Table 2

Comparison of intraoperative respiratory parameters between 20° and 25° head-down tilt.

	Group A (20° head-down tilt) N = 17 Mean (95% confidential interval)	Group B (25° head-down tilt) N = 10 Mean (95% confidential interval)	<i>P</i>
PEEP (cmH ₂ O)			
T2	7.4 (6.6–8.1)	8.0 (7.0–9.0)	N.S.
T3	7.7 (7.0–8.3)	8.1 (7.0–9.2)	N.S.
TV (mL)			
T1	461 (421–501)	444 (368–519)	N.S.
T2	422 (395–495)	465 (409–521)	N.S.
T3	412 (378–450)	412 (351–473)	N.S.
P mean (cmH ₂ O)			
T1	11.8 (11.1–12.6)	11.0 (8.6–13.6)	N.S.
T2	14.6 (13.5–15.6)	15.5 (14.3–16.7)	N.S.
T3	15.1 (14.0–16.3)	15.8 (14.7–17.1)	N.S.
P peak (cmH ₂ O)			
T1	18.7 (17.3–20.1)	19.7 (17.5–21.9)	N.S.
T2	25.3 (23.2–26.9)	28.8 (26.5–29.5)	0.011
T3	26.4 (24.2–27.8)	28.4 (24.2–31.7)	N.S.
T2-T1	6.4 (5.4–7.3)	8.5 (6.8–10.2)	0.015

PEEP, positive end-expiratory pressure; TV, tidal volume; P mean, mean airway pressure; P peak, peak airway pressure; T1, prior to head-down tilt; T2, at 60 min after the establishment of the Trendelenburg position and pneumoperitoneum; T3, at 120 min after the establishment of the Trendelenburg position and pneumoperitoneum, N.S., not significant.

Table 3
Effect of BMI on intraoperative respiratory parameters.

	BMI < 40 N = 19 Mean (95% confidential interval)	BMI ≥ 40 N = 8 Mean (95% confidential interval)	P
PEEP (cmH ₂ O)			
T2	7.2 (6.6–7.7)	8.6 (7.4–9.9)	0.011
T3	7.4 (6.9–7.9)	8.9 (7.7–10.1)	0.006
TV (mL)			
T1	443 (401–484)	484 (409–560)	N.S.
T2	418 (392–444)	484 (426–543)	0.012
T3	395 (364–426)	456 (386–525)	0.049
P mean (cmH ₂ O)			
T1	10.7 (9.7–11.1)	13.4 (12.4–14.4)	0.004
T2	14.3 (13.4–15.1)	16.5 (15.3–17.6)	0.004
T3	14.6 (13.6–15.5)	17.3 (16.3–18.3)	0.001
P peak (cmH ₂ O)			
T1	18.1 (16.9–19.2)	21.5 (19.6–23.5)	0.004
T2	25.3 (23.7–27.0)	28.4 (26.0–30.8)	0.035
T3	25.6 (23.6–27.0)	29.4 (27.1–31.7)	0.033

BMI, body mass index; PEEP, positive end-expiratory pressure; TV, tidal volume; P mean, mean airway pressure; P peak, peak airway pressure; T1, prior to head-down tilt; T2, at 60 min after the establishment of the Trendelenburg position and pneumoperitoneum; T3, at 120 min after the establishment of the Trendelenburg position and pneumoperitoneum; N.S., not significant.

Table 4
Comparison of intraoperative respiratory parameters in patients with BMIs ≥ 40.

	Group A (20° head-down tilt) N = 4 Mean (95% confidential interval)	Group B (25° head-down tilt) N = 4 Mean (95% confidential interval)	P
PEEP (cmH ₂ O)			
T2	8.5 (5.5–11.6)	8.8 (6.8–10.8)	N.S.
T3	9.0 (7.2–10.8)	8.8 (5.7–11.8)	N.S.
TV (mL)			
T1	461 (361–561)	507 (321–693)	N.S.
T2	464 (395–495)	506 (409–521)	N.S.
T3	477 (378–450)	436 (351–473)	N.S.
P mean (cmH ₂ O)			
T1	13.0 (10.8–15.3)	13.8 (12.2–15.3)	N.S.
T2	16.3 (14.3–18.3)	16.8 (14.4–19.1)	N.S.
T3	17.0 (15.2–18.8)	17.5 (15.5–19.6)	N.S.
P peak (cmH ₂ O)			
T1	20.8 (16.2–25.3)	22.3 (19.5–25.0)	N.S.
T2	27.5 (22.2–32.8)	29.8 (25.2–33.2)	N.S.
T3	28.5 (24.1–32.8)	30.5 (26.3–34.7)	N.S.

BMI, body mass index; PEEP, positive end-expiratory pressure; TV, tidal volume; P mean, mean airway pressure; P peak, peak airway pressure; T1, prior to head-down tilt; T2, at 60 min after the establishment of the Trendelenburg position and pneumoperitoneum; T3, at 120 min after the establishment of the Trendelenburg position and pneumoperitoneum, N.S., not significant.

40 kg/m². Some reports state that the incidence of complications does not differ significantly between patients with and without obesity undergoing robotic surgery (Kawai et al., 2021), and some suggest that the effect of a higher BMI on breathing during anesthesia is more significant than the effect of a lower head position (Sprung et al., 2002; Suh et al., 2010). In the present study, under PCV, a 5° difference in head-down tilt did not significantly affect respiratory status other than the P peak. Although an analysis of patients with a BMI ≥ 40 kg/m² found no significant difference in respiratory parameters between 20° and 25° of tilt, the airway pressure increased by nearly 30 cmH₂O at 25°, suggesting that steep head-down tilt was a significant respiratory load in patients with class III obesity. In this study, the average operating time was 228 (141–370) mins; therefore, it can be assumed that this time is fairly safe, even class III obesity; however, caution should be exercised if the surgery takes a long time.

Although robotic pelvic surgery is generally performed with a head-down tilt of 30–40°, we were able to perform all procedures with a tilt of

20–25°. Gould et al. reported that in 96 patients with an average BMI of 30 kg/m², an average head-down tilt of 28° provided a sufficient surgical field to perform the procedure safely (Gould et al., 2012). Ghomi et al. reported that 20 patients with an average BMI of 28.6 kg/m² could be operated on with an average head-down tilt of 16.4° (Ghomi et al., 2012). They concluded that a steep head-down tilt was not always necessary for gynecologic robot-assisted surgery. However, the study by Ghomi et al. did not include patients with class III obesity, so it is not possible to evaluate whether a head-down tilt of approximately 16° is sufficient in these patients.

A limitation of the current study is the small sample size and the lack of data for a head-down tilt > 30°. Therefore, it could not be confirmed whether a head-down tilt > 30° is safe in patients with class III obesity. Furthermore, only respiratory parameters were assessed, and no data were collected on central venous or intracranial pressure. Further studies must be conducted to determine the appropriate and safe angles for use in patients with obesity. Nevertheless, the strength of the current study was that from our results it can be concluded that Trendelenburg positioning at 20–25° does not affect respiration in patients with obesity and allows for surgery, even in patients with a BMI ≥ 40 kg/m².

In conclusion, under careful anesthetic management, effective oxygenation was maintained at an airway pressure of 30 cmH₂O or lower, even in patients with class III obesity, demonstrating the safety of robot-assisted laparoscopic surgery with 20–25° degrees of head-down tilt in these patients during hysterectomy for endometrial cancer and endometrial atypical hyperplasia. However, further research is needed to determine the appropriate and safe angle to use in patients with a BMI ≥ 40 kg/m².

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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