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Effects of steep Trendelenburg position and pneumoperitoneum on middle ear pressure in patients undergoing robotic radical prostatectomy

Fusun BOZKIRLI, Nurdan BEDİRLİ*, Mehmet AKÇABAY
Department of Anesthesiology, Faculty of Medicine, Gazi University, Ankara, Turkey

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Background/aim: The aim of this study was to quantify the changes in middle ear pressure (MEP) during robot-assisted radical prostatectomy (RARP).

Materials and methods: Thirty patients undergoing RARP were included in this study. MEP was obtained at the following time points: awake (T1), postintubation (T2), pneumoperitoneum + 1 h of Trendelenburg position (T3), pneumoperitoneum + 2 h of Trendelenburg position (T4), pneumoperitoneum + 3 h of Trendelenburg position (T5), desufflation + supine position (T6), and 1 h after extubation in the postanesthesia care unit (T7). Heart rate, mean arterial pressure (MAP), peak airway pressure (PAP), tidal volume, minute ventilation, $EtCO_2$, and blood gas values were recorded.

Results: MEP was significantly higher at T4, T5, T6, and T7 as compared to T1 values. PAP values were significantly increased at T3, T4, and T5 compared to T2. MAP values at T3, T4, and T5 were significantly higher compared to T1. $PaCO_2$ increased significantly at T4, T5, and T6 and pH decreased significantly at T4 and T5 when compared to T2.

Conclusion: The combination of steep Trendelenburg position and pneumoperitoneum during RARP caused a significant increase in MEP, $PaCO_2$, and $EtCO_2$ levels. This propensity for increased MEP may cause problems in patients with preexisting ear disease.

Key words: Pneumoperitoneum, steep Trendelenburg position, middle ear pressure

1. Introduction

The robot-assisted laparoscopic technique is a significant improvement in the surgical field because this new technique offers several advantages like better visualization, better dissection, reduced blood loss, decreased analgesic requirement, and shortened hospital stay (1–3). Robot-assisted radical prostatectomy (RARP) is one of the most common applications of robotic laparoscopic surgeries. However, RARP brings new challenges to the anesthesia field because it requires a steep Trendelenburg position and pneumoperitoneum.

Some nonphysiological changes in the cardiovascular, cerebrovascular, and respiratory systems related to steep Trendelenburg positioning combined with pneumoperitoneum were well defined (4–8). However, the effects of the steep Trendelenburg position combined with pneumoperitoneum on middle ear pressure (MEP) have not been studied.

The middle ear cavity is covered by mucosa filled with gas and has a constant pressure during physiologically normal activities (9). Increase in MEP causes an increase in intratympanic pressure, which may result in membrane rupture and hearing loss (10,11). It was reported that factors such as supine position, general anesthesia, and airway management increased the MEP (12–14).

The current information about the changes of MEP during RARP under general anesthesia is not sufficient. The aim of this study was to quantify the changes in MEP caused by steep Trendelenburg position combined with pneumoperitoneum in patients undergoing RARP.

2. Materials and methods

2.1. Ethics statement

The study protocol was reviewed according to the Declaration of Helsinki and approved by the Human Ethics Committee of Gazi University (decision number: 125; decision date: 27.04.2011). The written informed consent of all the patients was obtained.

2.2. Patients

Thirty-five patients, of American Society of Anesthesiologist (ASA) physical status I–III and aged 18–80, undergoing RARP in the steep Trendelenburg position

* Correspondence: nurbedirli@yahoo.com

were included in this prospective observational study. Five patients were excluded from the study because of technical problems. No premedication was administered. Patients with a history of ear disease, pressure equilibrium problems, or abnormal otomicroscopic examination were excluded from the study.

2.3. Method

In the operating room, standard monitoring was applied including ECG, pulse oximetry, and noninvasive automated arterial pressure. Anesthesia was induced with lidocaine (1 mg kg^{-1}), propofol (2–3 mg kg^{-1}), and remifentanil (0.3–0.5 µg kg^{-1} min^{-1}). Tracheal intubation was facilitated with rocuronium (0.6 mg kg^{-1}). After induction, a 20-G cannula was inserted into the radial artery in order to measure the beat-to-beat arterial pressure and for arterial blood sampling. Anesthesia was maintained with infusions of remifentanil (0.05–0.2 µg kg^{-1} min^{-1}) and propofol (6–10 mg kg^{-1} h^{-1}). The propofol and remifentanil dosage range was planned according to mean arterial pressure (MAP) and heart rate (HR). If MAP dropped >20% from the baseline, the propofol concentration was reduced to 6 mg kg^{-1} h^{-1}. If HR dropped >20% from the baseline, the remifentanil concentration was reduced to 0.05 µg kg^{-1} min^{-1}. If HR failed to normalize or the fall in the HR was <50 beats min^{-1} then the decrease in HR was treated with 0.3 mg of atropine intravenously. If HR or MAP increased by >20% of baseline, the propofol concentration was increased to 10 mg kg^{-1} h^{-1} and intravenous fentanyl boluses of 10 µg were given if MAP failed to normalize.

The lungs were ventilated in volume control mode with an O_2/air mixture (FiO_2 0.4) and patients were mechanically ventilated with a tidal volume (V_T) of 8–10 mL kg^{-1}, inspiratory/expiratory ratio of 1:2, and 2.0 L min^{-1} of inspiratory fresh gas flow. Respiratory rate was set according to the end tidal carbon dioxide pressure ($EtCO_2$) value. Body temperature was maintained at 36–37 °C using a forced air warming system.

Pneumoperitoneum was created by intraperitoneal insufflation of CO_2 to a pressure of 15 ± 5 mmHg. The surgeon performed the procedure at a control table located away from the operating table using the da Vinci robot surgical system (Intuitive Surgical, Sunnyvale, CA, USA). Tympanometry recordings were obtained in sequence for both ears by tympanometry (tympanometer, Otowave 102-4, Amplivox, Eynsham, UK) and reported in units of mmH_2O.

The MEP of the patients was measured at the following time points: awake (T1), postintubation (T2), pneumoperitoneum + 1 h of Trendelenburg position (T3), pneumoperitoneum + 2 h of Trendelenburg position (T4), pneumoperitoneum + 3 h of Trendelenburg position (T5), desufflation + supine position (T6), and 1 h after extubation in the postanesthesia care unit (T7). Furthermore, HR, MAP, peak airway pressure (PAP), tidal volume (TV), minute ventilation (MV), $EtCO_2$, and blood gas tension values were recorded at the T2, T3, T4, T5, and T6 measurement times.

Neuromuscular block reversal was managed with a mixture of atropine (10 µg kg^{-1}) and neostigmine (20 ***µg*** kg^{-1}) and the patients were extubated when the tidal volume was >5–7 mL kg^{-1} with a frequency of 10–12 per minute. Postoperative analgesia was initiated with tramadol (1 mg kg^{-1}) and the patients were transferred to the postoperative care unit.

2.4. Statistical analysis

Statistical analysis was performed using SPSS 15.0 for Windows. Demographic and hemodynamic variables were evaluated using repeated measures of ANOVA. The MEP measurements for both ears at all measurement times were compared using a paired t-test. $P < 0.05$ was considered as statistically significant.

3. Results

Data from 30 patients were used in the study. Three patients were excluded from the study because MEP data at the T3 and T4 measurement times could not be obtained due to tympanometry calibration problems, and 2 patients were excluded from the study because postoperative MEP measurements (T7) could not be obtained. The enrolled data were normally distributed and are presented as median (range) or mean (SD). The demographics of the patients were similar and are summarized in Table 1. Median patient age was 66 (48–73) years and the total time spent in the steep Trendelenburg position was 200 (185–225) min.

Table 1. Patients' characteristics and operative data.

Patient characteristics and operative data	Median (range)
Age (years)	66 (46–73)
BMI (kg m^{-2})	29 (22–36)
ASA I II III	n* 11 17 2
Operation time (min)	240 (210–260)
Trendelenburg time (min)	200 (185–225)
Blood loss (mL)	75 (50–100)
Intravenous fluid (mL)	2300 (1800–2600)

*Data of ASA physical status given as number of patients.

Respiratory and hemodynamic data are given in Tables 2 and 3. PAP values showed a significant increase at T3, T4, and T5 when compared to T2. TV and MV were significantly decreased at T3, T4, and T5 when compared to T2. HR values did not show a significant difference over the time periods while MAP values at T3, T4, and T5 were significantly higher compared to T1. $EtCO_2$ levels at T4, T5, and T6 were significantly higher when compared to T2.

Blood gas variables are shown in Table 4. PaO_2 did not change significantly with pneumoperitoneum and Trendelenburg position and it remained within the normal range all through the surgery. $PaCO_2$ increased and pH decreased 1 h after Trendelenburg positioning (T3), but the difference was only significant at T4, T5, and T6 for $PaCO_2$ and at T4 and T5 for pH when compared to T2.

Table 5 shows the mean MEP for both right and left ears in the supine and the Trendelenburg positions with

Table 2. Respiratory data of the patients.

	T2	T3	T4	T5	T6
SpO_2 (%)	99	98	99	98	98
$EtCO_2$ (mmHg)	34 ± 4	38 ± 6	51 ± 3*	48 ± 5*	49 ± 8*
PAP (cmH_2O)	15 ± 4	24 ± 3*	26 ± 2*	26 ± 4*	17 ± 3
TV (mL)	690 ± 75	510 ± 20*	520 ± 15*	530 ± 12*	670 ± 30
MV (L)	7 ± 1	6.0 ± 1.3*	5.4 ± 1.2*	6.1 ± 1.4*	6.9 ± 1.4

*P < 0.05 compared to T2 measurement time.

Table 3. Hemodynamic data of the patients.

	T1	T2	T3	T4	T5	T6	T7
HR (beats min^{-1})	72 ± 8	68 ± 10	64 ± 7	61 ± 5	65 ± 8	66 ± 8	67 ± 11
MAP (mmHg)	73 ± 12	87 ± 10	110 ± 6*	109 ± 14*	98 ± 15*	71 ± 12	70 ± 18

*P < 0.05 compared to T1 measurement time.

Table 4. Blood gas values of the patients.

	T2	T3	T4	T5	T6	T7
pH	7.38 ± 0.05	7.35 ± 0.03	7.31 ± 0.02*	7.29 ± 0.05*	7.37 ± 0.05	7.39 ± 0.06
PaO_2	175 ± 20	173 ± 21	169 ± 15	170 ± 18	170 ± 15	120 ± 10
$PaCO_2$	35 ± 6	40 ± 8	57 ± 7*	54 ± 5*	50 ± 7*	45 ± 7
HCO_3	24 ± 5	25 ± 7	25 ± 3	25 ± 1	24 ± 5	24 ± 4

*P < 0.05 compared to T2 measurement time.

Table 5. Middle ear pressure (MEP) values of the patients.

	T1	T2	T3	T4	T5	T6	T7
MEP, right	3.81 ± 1.78	3.98 ± 1.23	15.87 ± 5.34*	47.34 ± 12.6*	43.87 ± 11.5*	44.78 ± 9.81*	43.25 ± 4.56*
MEP, left	4.17 ± 2.43	4.97 ± 1.34	12 ± 4.71*	46 ± 9.8*	43.15 ± 10.8*	41.18 ± 5.41*	41.17 ± 3.16*

*P < 0.05 compared to T2 measurement time.

or without pneumoperitoneum against time. Pressures for right and left ears were similar at every measurement time. MEP reached its maximum value at T4 and the difference was significant compared to T1 values; moreover, this significant increase continued all through the study. The MEP of both left and right ears was significantly higher at T3, T4, T5, T6, and T7 compared to T1.

4. Discussion

Robot-assisted surgery became an alternative to conventional surgery and will likely play an increasingly large role in the future of surgical practice. The technology of robotic assistance overcame the limitations of conventional laparoscopy, providing improved surgical precision, better visualization, and better instrument control, and has become an alternative to conventional radical prostatectomy (1–3).

RARP management needs steep Trendelenburg positioning and CO_2 pneumoperitoneum, which causes challenges for anesthesiologists because of changes in cardiovascular, respiratory, metabolic, and cerebral physiology. Hemodynamic and respiratory changes may result in increases in airway pressure, hypoxemia, pulmonary hypertension, pulmonary edema, heart failure, and increases in intracranial pressure (4–8). Furthermore, Award et al. (15) showed that intraocular pressure increases significantly and this increase is affected by surgical time and $EtCO_2$ level in anesthetized patients undergoing robotic radical prostatectomy.

In this study, we evaluated the effects of steep Trendelenburg position combined with CO_2 pneumoperitoneum on MEP and respiratory variables in patients undergoing RARP surgery with propofol and remifentanil infusion. Our results showed that CO_2 pneumoperitoneum and Trendelenburg positioning caused an increase in arterial pressure, PAP, and MEP and a decrease in tidal volume. Respiratory results were as expected and compatible with the literature (4). Investigating the MEP changes related to the steep Trendelenburg position and CO_2 pneumoperitoneum was our primary purpose. The results of this study showed that MEP increased significantly in patients undergoing RARP under propofol and remifentanil anesthesia and this increase continued until the postoperative first hour, which was the endpoint of our study.

The MEP is regulated by the Eustachian tube, the gas exchange through the middle ear mucosa, and central neural mechanisms (14,16). Studies showed that, besides diseases related to the middle ear, sleeping, body position, and anesthesia also play an important role in regulation of the MEP (11–14,17). Cinamon et al. (13) studied the MEP changes related to body position and concluded that body posture had a significant, immediate, and reversible effect on MEP. In the present study the steep Trendelenburg position combined with pneumoperitoneum caused a significant increase and this increase continued to the postoperative first hour. This prolonged response may be related to the degree and the time of the Trendelenburg position or CO_2 diffusion to the middle ear.

Results of clinical studies suggested that volatile anesthetics might cause an increase in MEP and total intravenous anaesthesia (TIVA) was the optimal choice to maintain MEP within the normal range (11,12,18,19). In this study, to isolate the effects of Trendelenburg position combined with pneumoperitoneum independently of the effects of anesthesia, TIVA with propofol and remifentanil was preferred.

Gas diffusion and gas transport between the blood vessel and middle ear cavity is a suggested mechanism that plays a role in MEP regulation (13). The results of the present study showed that MEP reached its peak value at 2 h of Trendelenburg positioning and pneumoperitoneum. At this measurement time, the $EtCO_2$ and $PaCO_2$ levels were also at their highest values. These results suggest that the prolonged increase in MEP was primarily the result of elevated CO_2 levels in the blood and its passage to the middle ear cavity.

Increase in MEP may cause some undesirable clinical outcomes. MEP changes may lead to postoperative intractable nausea and vomiting (20). Furthermore, rupture of membranes and even facial nerve damages may occur as a result of significant and long-term increases in MEP (21,22). These undesired side effects are challenges alongside the benefits of minimally invasive surgeries and therefore alternations in MEP during RARP are important. Furthermore, the MEP increase in our study seems to be independent of preexisting problems because in this study patients with a history of ear diseases were excluded. Therefore, we cannot speculate on the degree of MEP alternations and related complications during RARP in patients who have coexisting middle ear diseases and further studies are needed to evaluate the MEP alternations in these patients.

In conclusion, the results of this study showed that the combination of steep Trendelenburg position and pneumoperitoneum during RARP caused a significant increase in MEP and this pressure elevation was simultaneous with the elevation of $PaCO_2$ and $EtCO_2$ levels. Although the magnitude of this increase was within the normal range and none of our patients suffered from ear problems postoperatively, this propensity for increase in MEP may cause problems in patients with preexisting disease. We recommend a detailed anamnesis of ear diseases and consultation with an ear, nose, and throat specialist during preanesthetic evaluation of patients who will have RARP surgery.

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