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The relationship between the Trendelenburg position and cerebral hypoxia in patients who have undergone robot-assisted hysterectomy and prostatectomy

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Background/aim: This study aimed to evaluate the relationship between the Trendelenburg position and cerebral hypoxia in robot-assisted hysterectomy and prostatectomy.

Materials and methods: A standardized mini-mental state examination was administered to 50 patients enrolled in the study 1 h before and after surgery. Near infrared spectroscopy (NIRS) values and hemodynamic and respiratory parameters were recorded after induction of anesthesia (baseline) and once every 20 min in the Trendelenburg position and supine positions. The relationship between the development of cerebral desaturation and the patient's position was examined.

Results: For all patients, the baseline mean cerebral oxygen saturation (RSO_2) on the right and left were 70.5 ± 7.3% and 70.6 ± 6.7%, respectively. Right RSO_2 values at 20 min and 60 min in the Trendelenburg position decreased significantly, but they increased at 120 min. A significant positive correlation was found between right RSO_2 and $EtCO_2$ in the supine period following surgery, and between left RSO_2 and $EtCO_2$ at 60 min in the Trendelenburg and supine positions. The relationship between NIRS values and cognitive dysfunction was not significant.

Conclusion: We found that cerebral saturation decreases as age increases, and cerebral desaturation may occur owing to the Trendelenburg position. There was no correlation between patients' cognitive function and NIRS values.

Key words: Laparoscopy, near infrared spectroscopy, robotic surgery, cerebral hypoxia, Trendelenburg position

1. Introduction

Cerebral oxygen metabolism could be affected during robot-assisted laparoscopic prostatectomy and hysterectomy, owing to changes in intracranial pressure (ICP) and cerebral blood flow (CBF), resulting from both the steep Trendelenburg position and CO_2 pneumoperitoneum (1). An increase in intracranial pressure due to the Trendelenburg position could lead to hypoxia in the brain, low arterial oxygen content, ischemia, and high oxygen consumption in the brain. In order to prevent the impairment of cerebral function, there is a need for methods that can determine the start of desaturation and enable early intervention. Methods known as near infrared spectroscopy (NIRS) offer a constant, noninvasive, and safe method of determining cerebral desaturation. Noninvasive monitoring of cerebral oximetry provides great convenience in the evaluation of cerebral hypoxia. In a study evaluating the correlation between cerebral NIRS and somatic NIRS (renal), and central venous oxygen saturation received via catheter, a significant statistical correlation was found between cerebral NIRS values and central venous oxygen values (2). Yueying et al. (3) compared NIRS with transcranial Doppler monitoring and revealed a correlation between impaired autoregulation of cerebral blood flow and low NIRS values.

The detection of cerebral desaturation can change the patient's treatment and prevent problems related to postoperative brain function. When problems related to cerebral function are prevented, the length of stay in intensive care and time until hospital discharge are reduced.

In this study, we aimed to evaluate the relationship between the Trendelenburg position and cerebral hypoxia in a total of 50 patients undergoing robot-assisted laparoscopic hysterectomy and prostatectomy.

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2. Materials and methods

Our study was conducted on a total of 50 patients who were admitted to the gynecology and obstetrics or urology clinics for robot-assisted laparoscopic hysterectomy or prostatectomy. Approval was obtained from the hospital's ethics committee and written, informed consent was received from all patients. Our study is a prospective observational study, and the operating team performed the requirements of the surgery without knowing the NIRS values.

A preoperative standardized mini-mental state examination (SMMSE) was administered to all patients 1 h before the procedure. Patients were received in the operating room after a minimum of 6 h of preoperative fasting, as required by standard procedures for general anesthesia. Following this, vascular access was established through a 16–18-gauge cannula, and intravenous rehydration was initiated with a 1000-mL crystalloid solution. Standard EKG, pulse oximetry, and noninvasive blood pressure were monitored. After cleaning the patient's forehead with alcohol-soaked cotton, two NIRS probes were placed, and the values seen on the monitor were recorded as T1. Following this, endotracheal intubation was performed after intravenous administration of 0.5 mg of atropine (0.5 mg; Galen İlaç Sanayi, İstanbul, Turkey), 1–2 mg/kg propofol (propofol 1%, 20 mL ampule; Fresenius Kabi, Linz, Austria), 1.5-2 µg/kg fentanyl (0.5 mg, 10 mL; Vem İlaç Sanayi, İdol İlaç Dolum, İstanbul, Turkey), and 0.6 mg/kg rocuronium (Esmeron 50 mg, 5 mL vial; Organon, Oss, the Netherlands). Anesthesia was maintained with desflurane (end tidal concentration 4%–6%, tidal volume 8–10 mL/kg), and an infusion of remifentanil at 0.05–1 µg/kg per minute (Ultiva 5 mg vial, Brentford, UK), accompanied by 50% O_2 and 50% air. A cannula was inserted in the radial artery and invasive artery pressure (IAP) was monitored. Arterial blood gas was then recorded as a baseline and subsequently checked once every 60 min. Values on the NIRS monitor were recorded as T2 after anesthesia, T3 following Trendelenburg positioning, T4 after desufflation, and then as left and right (LSO_2-RSO_2) once every 20 min until the patient was returned to a supine position. While recording these values, patients' systolic arterial pressure (SAP), diastolic arterial pressure (DAP), mean arterial pressure (MAP), oxygen saturation, heart rate (HR), end-tidal CO_2 ($EtCO_2$), and intraabdominal pressure (IAP) were also recorded. All parameters were recorded again 10 min after the patient was returned to a supine position at the end of the surgery. The SMMSE was administered again 1 h after surgery. The cerebral desaturation rates of patients were measured, and it was statistically determined whether these were correlated with complications.

2.1. Statistical method

The mean, standard deviation, median, minimum, maximum, frequency, and ratio were used in the definitive statistics of the study. The distribution of variables was measured with the Kolmogorov–Smirnov test. An independent samples t-test was used in the analysis of quantitative data. For the analysis of repeated measurements, repeated measures analysis of variance, the matched samples t-test, and the Wilcoxon test were used. The Pearson and Spearman correlation methods were selected for correlation analysis. SPSS 22.0 (IBM Corp., Armonk, NY, USA) was used in the analyses.

3. Results

The demographic data for the 50 patients in our study are presented in Table 1. The mean age of our patients was 62.9 ± 6.8 years.

When comparing baseline RSO_2 with intraoperative values at times T, T40, T80, T100, T120, T140, T160, T180, and supine, a statistically significant reduction was determined in RSO_2 between T20 and T60 ($P < 0.05$). The RSO_2 value was significantly higher at T120 compared to the baseline (Figure). A significant change was not observed in the LSO_2 value at any time compared to the baseline. There was no significant change in RSO_2 and LSO_2 values at T20, T40, T60, T80, T100, T120, T140, T160, T180, and supine time points when compared to the previous time point.

The patients' hemodynamic parameters are presented in Table 2. Heart rate was significantly lower at T, T20, T40, T60, T80, T100, and T120 compared to the baseline measurement. However, no significant change was observed in heart rate at T140, T160, T180, or supine.

There was no significant change in SAP, DAP, or MAP values at the T, T20, T40, T60, T80, T100, T120, T140, T180, and supine time points compared to the baseline. Systolic arterial pressure was significantly lower at T160 compared to the baseline (Table 2). There was no significant change in SAP, DAP, or MAP values at T20, T40, T60, T80, T100, T120, T140, T160, T180, and supine time points compared to the previous measurement.

The patients' respiratory parameters are presented in Table 3. A significant change was not observed in PaO_2 and $EtCO_2$ values during the operative period compared to baseline values. Compared to the baseline, a significant increase was seen in SpO_2 values at time points T40, T100, and T160. There was also a significant increase in $PaCO_2$ at T100 and T160.

During the T, T60, and supine periods, there was a significant positive correlation between the rate of change in RSO_2 and LSO_2 compared to the baseline ($P < 0.05$) (Figure). A significant correlation was also found between the rate of change in RSO_2 and the MAP and $EtCO_2$ values

Table 1. Patient demographic data.

Age (years)	Mean ± SD	N (%)
	62.9 ± 6.8	50
Sex Male Female		 45 (90%) 5 (10%)
Weight (kg)	82.4 ± 12.3	
Height (cm)	171.2 ± 7.6	
Additional diseases No Yes		 25 (50%) 25 (50%)
Operation duration (min)	154.0 ± 50.7	
Amount of fluid administered Crystalloid Colloid	 1584 ± 509 38.0 ± 99.8	
Amount of bleeding (mL)	67.4 ± 102.8	

Mean values ± standard deviation, N (%): number of patients (percentage).

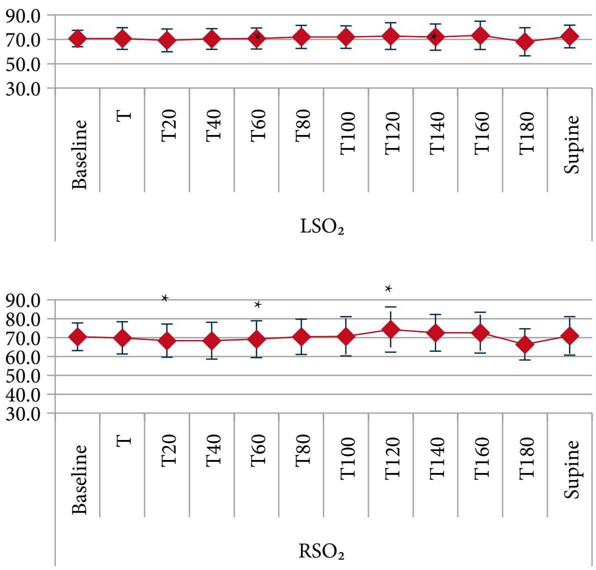

Figure. RSO_2 and LSO_2 values.
* $P < 0.05$; B: baseline; T: Trendelenburg position; T20, T40, T60, T80, T100, T120, T140, T160, T180: 20, 40, 60, 80, 100, 120, 140, and 180 min after Trendelenburg position; S: after return to supine position.

during the supine period compared to the baseline. RSO_2 had a negative correlation with MAP and a negative correlation with $EtCO_2$.

During the T40 period, there was a significant negative correlation between the rate of change in LSO_2 and the SAP, DAP, and MAP values. A significant negative correlation was seen with DAP during T60, and with MAP during the supine period. During the T60 and supine periods, a significant positive correlation was observed between the LSO_2 and $EtCO_2$ values compared to the baseline (Table

Table 2. Changes in hemodynamic parameters.

Hemodynamic data				
	HR	SAP	DAP	MAP
B	78.4 ± 11.9	147.1 ± 25.8	82.2 ± 17.2	105.6 ± 20.6
T	70.8 ± 10.2*	132.7 ± 21.6	83.9 ± 12.7	99.3 ± 15.3
T20	67.1 ± 9.3*	116.8 ± 18.1	76.0 ± 10.8	88.9 ± 11.7
T40	66.5 ± 9.3*	110.2 ± 16.7	71.4 ± 9.9	83.0 ± 10.8
T60	67.1 ± 10.8*	107.7 ± 18.9	71.0 ± 10.8	81.9 ± 12.4
T80	68.7 ± 12.0*	111.5 ± 18.3	71.7 ± 12.3	84.1 ± 13.7
T100	67.6 ± 10.8*	112.9 ± 16.2	69.8 ± 10.0	82.5 ± 10.4
T120	66.7 ± 10.3*	117.1 ± 10.2	77.0 ± 8.8	89.3 ± 9.2
T140	66.4 ± 11.4	118.7 ± 13.2	98.0 ± 35.5*	90.3 ± 11.9
T160	71.9 ± 12.1	98.0 ± 35.5*	75.3 ± 8.7	85.9 ± 9.2
T180	72.0 ± 13.3	112.2 ± 17.2	74.6 ±10.4	85.6 ± 9.5
S	68.6 ± 10.8	109.4 ± 17.6	66.1 ± 11.4	79 ± 10.6

*P < 0.05; B: baseline; T: Trendelenburg position; T20, T40, T60, T80, T100, T120, T140, T160, T180: 20, 40, 60, 80, 100, 120, 140, 160, and 180 min after Trendelenburg position; S: after return to supine position; HR: heart rate; SAP: systolic arterial pressure; DAP: diastolic arterial pressure; MAP: mean arterial pressure.

Table 3. Patients' respiratory parameters.

Respiratory parameters				
	B	T40	T100	T160
PaO_2 (kPa)	173.4 ± 66.6	144.9 ± 37.8	172.2 ± 63.9	145.8 ± 34.9
$PaCO_2$ (kPa)	34.4 ± 4.7	38.9 ± 6.3	39.3 ± 5.3*	41.4 ± 3.4*
$EtCO_2$ (mmHg)	34.6 ± 3.4	36.6 ± 4.0	37.8 ± 4.1	38.3 ± 3.6
SpO_2	98.8 ± 0.8	98.4 ± 1.3*	98.5 ± 1.4*	98.4 ± 0.6*

*P < 0.05; B: baseline, T40: 40 min after Trendelenburg position, T100: 100 min after Trendelenburg position, T160: 160 min after Trendelenburg position; PaO_2: partial arterial oxygen pressure, $PaCO_2$: partial arterial carbon dioxide pressure, $EtCO_2$: end tidal carbon dioxide pressure, SPO_2: saturation.

4). A statistically significant decrease was observed in patients' postoperative SMMSE scores compared to the preoperative period; however, there was no significant correlation with RSO_2 or LSO_2 (Table 5).

4. Discussion

During robot-assisted laparoscopic prostatectomy and hysterectomy operations, cerebral oxygen metabolism could be affected by changes in ICP and CBF, resulting from both the steep Trendelenburg position and CO_2 pneumoperitoneum (1).

The Trendelenburg position causes both the patient's MAP and CVP to rise, which leads to an increase in the hydrostatic pressure of the brain. Studies have reported that cerebral perfusion pressure decreases if the position lasts for longer than 165 min (4). It is also emphasized that the duration of the operation should not be longer than 3 h in order to avoid neurological dysfunction. Cerebral autoregulation has been observed to deteriorate when the Trendelenburg position lasts for more than 170 min and a case with brain edema and pathophysiologic changes in neuronal function was attributed to the operation

Table 4. Time and systolic, diastolic, and mean arterial pressures of RSO_2 and LSO_2, and correlation coefficients and significance between SpO_2 and $EtCO_2$.

			LSO_2	SAP	DAP	MAP	SPO_2	$EtCO_2$
RSO_2								
Change as per baseline	T	p	0.001*	0.622	0.582	0.748	0.165	0.541
	T20	p	0.099	0.345	0.500	0.312	0.831	0.413
	T40	p	0.060	0.559	0.874	0.790	0.999	0.654
	T60	p	0.007*	0.236	0.406	-0.310	0.496	0.688
	Supine	p	0.000*	0.068	0.061	0.029*	0.775	0.046*
LSO_2								
Change as per baseline	T	p		0.622	0.628	0.695	0.386	0.348
	T20	p		0.593	0.704	0.583	0.174	0.325
	T40	p		0.018*	0.017*	0.018*	0.653	0.359
	T60	p		0.100	0.043*	0.056	0.346	0.012*
	Supine	p		0.062	0.028*	0.025*	0.398	0.017*

*$P < 0.05$; T: Trendelenburg position; T20, T40, T60: 20, 40, and 60 min after Trendelenburg position; SAP: systolic arterial pressure; DAP: diastolic arterial pressure; MAP: mean arterial pressure; SpO_2: peripheral oxygen saturation; $EtCO_2$: end tidal carbon dioxide.

Table 5. Correlation between preoperative and postoperative SMMSE scores.

	Min–max	Median	Mean ± SD	P
SMMSE score				
Preoperative	15.0–30.0	26.0	25.3 ± 3.8	0.000*
Postoperative	14.0–30.0	24.0	24.1 ± 3.8	

*$P < 0.05$; SMMSE: standardized mini-mental state examination.

exceeding 8 h in duration, with excessive Trendelenburg position and pneumoperitoneum (5). There are also publications reporting that increasing ICP, CBP, and CBV and decreasing carotid artery blood flow may negatively affect cerebral tissue oxygenation in patients with intracranial lesions during laparoscopy (6,7). Harvey et al. (8) suggested that the decrease in rSO_2 could be caused by prevention of venous return, and that the patient's head must be straightened. Fujiwara et al. (9) observed a significant level of slowdown in EEG along with a decrease in rSO_2 in patients whose heads were tilted 45° to 50° upwards. All this information gives rise to the suggestion that position could be important in increasing rSO_2.

When pneumoperitoneum is performed in robot-assisted laparoscopic surgeries, cerebral blood flow may increase as a result of the increase in $PaCO_2$. There are also publications suggesting that catecholamine release might lead to this (10,11). Cerebral vasodilatation due to hypercapnia also increases cerebral blood flow. Changes in cerebral blood flow are stated as being proportional to the changes in $PaCO_2$ within the 2.7–8.0 kPa range (12). Kolb et al. (13) concluded that both rSO_2 and central cerebral artery flow increase in hypercapnia. Hypercapnia might lead to the changes in CBF caused by pneumoperitoneum. It was shown in these studies that changes in CBF during laparoscopy could be related to the increase in $PaCO_2$ (14). Since $PaCO_2$ is one of the important parameters in determining CBF, hypercapnia and hypocapnia were considered when there was no response to other treatments (15). Studies suggest that the creation of pneumoperitoneum with CO_2 in patients with normal ICP would not lead to a decrease in rSO_2 alone, unless the patient was hypercapnic. As long as patients have normal $PaCO_2$ values, pneumoperitoneum does not cause changes in CBF and therefore normocapnia is important in terms of cerebral oxygenation (16,17). In our study, we kept the IAP between 12 and 15 mmHg since CO_2 pneumoperitoneum leads to hemodynamic changes with an increase in IAP and could cause cerebral desaturation, and patients were normocapnic during the operation. A significant inverse relationship was found between RSO_2 and $EtCO_2$. With an increase in $EtCO_2$, a significant decrease was seen in RSO_2. This result is similar to that observed in other studies. During the supine period, there was a significant positive correlation between the change in RSO_2 and $EtCO_2$ change as per baseline.

O'Malley and Cunningham (18) reported that an increase in MAP could lead to pressure on the aorta with raised intraabdominal pressure and an increase in afterload during laparoscopy. Schman et al. (19) reported that high blood pressure during the Trendelenburg position could be a trigger or an aggravating factor in the development of cerebral edema. They particularly emphasized that MAP should be kept within the normal range. They also stated that the high mean blood pressure following the Trendelenburg position would not have a significant effect thanks to cerebral autoregulation but could lead to serious complications such as cerebral bleeding or edema. In our study, there was a negative correlation between MAP and RSO_2. Values recorded during the supine period showed a significant negative correlation between the change in RSO_2 and the change in MAP with respect to baseline values.

There are studies suggesting that cerebral tissue oxygen saturation ($SctO_2$) specifically decreases in elderly patients in the Trendelenburg position (20). Robot-assisted prostatectomy patients are generally elderly, and establishing a balance between the need for cerebral oxygen and the need to support these patients can be critical (21). Hung et al. (22) measured the basal rSO_2 values as 83 ± 6.1% and 77.3 ± 6.1% in young and old patient groups, respectively. The maximum drop from the basal rSO_2 value was 7.5% and 10.9% in young and old patients, respectively. In this study, which evaluates the effect of the induction of anesthesia in terms of cerebral hypoxia, although there was a reduction in MAP, the decrease in rSO_2 was not statistically significant in the young or old patient groups (22). In our study, while basal rSO_2 was observed to be lower in elderly patients, a significant correlation was not found between changes in rSO_2 and the Trendelenburg position.

In a study carried out to observe the utility of NIRS, a group of patients was monitored intraoperatively with NIRS while another group was not, and postoperative cognitive function was observed to be better in the monitored patients. The researchers suggested that this was a result of necessary intervention when cerebral hypoxia was detected (23). In a study to evaluate the effects of intraoperative NIRS monitoring on the incidence of regression in neurocognitive functions, following coronary artery bypass surgery, Colak et al. (24) maintained the rSO_2 of the group monitored with NIRS over 80% of the basal value, or 50% as an absolute value. The results of a cognitive evaluation performed 7 days after the operation showed that cognitive function in the group monitored with NIRS was higher compared to the other group. They concluded that extended rSO_2 desaturation is an important parameter in cognitive regression, and intraoperative cerebral oximeter monitoring contributes significantly to the cognitive scores of patients postoperatively. Schramm et al. (19) observed neurological dysfunction in only one case after the Trendelenburg position. They claimed that the duration of the operation had been too long in this case, and this was the cause of the dysfunction. There are many preoperative factors affecting postoperative cognitive function. Studies suggest that old age, major surgery, and a low level of education lead to postoperative cognitive dysfunction (25,26). Jo et al. (27) reported that cognitive impairment in elderly patients following major surgery occurred in patients over 60, with a low level of education. In our study, there was no significant correlation between NIRS and cognitive dysfunction. However, we observed a significant decrease in cognitive function postoperatively when compared to preoperative cognitive function. This is to be expected, considering the difficulty of the surgery and that most of the patients were over 60 years old.

Our findings show that hemodynamic and respiratory changes in patients undergoing robot-assisted laparoscopic surgery affect the development of cerebral hypoxia. It must be considered that changes due to both the Trendelenburg position and pneumoperitoneum may have negative effects on cerebral perfusion. We believe that performing cerebral monitoring, especially in elderly patients, owing to their predisposition to cerebral hypoxia, will be beneficial in terms of preventing the cerebral complications that may arise.

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