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Effect of head position during thyroidectomy on cerebral oxygenation and cognition: Prospective observational study

Postoperative cognitive function

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Abstract
Aim: In this study, we aimed to observe the effect of head position during thyroidectomy on carotid artery blood flow, cerebral oxygen saturation (rSO2) and postoperative cognitive dysfunction (POCD).
Material and Methods: Forty patients were included in the study. The time-average velocity (TAV), peak systolic velocity (PSV), end-diastolic velocity (EDV), flow volume (FV), carotid artery diameter (CAD), and resistance index (RI) of the common carotid artery were measured using Doppler ultrasonography when the patient was in supine position before anesthesia, after surgical position (semi fowler position with extension of the neck and head), and before position correction at the end of the surgery. Bilateral rSO2 values were monitored continuously. Cognitive functions were evaluated with the standardized mini-mental test.
Results: At the end of the operation, it was determined that FV, PSV, EDV, CAD and bilateral rSO2 values decreased compared to the initial values ($p < 0.05$). Early and late POCD were found to be 47.5% and 32.5%, respectively. No relationship was found between cerebral desaturation and POCD. It was observed that the decrease in FV might be related to early POCD ($p < 0.05$).
Discussion: The head position caused a decrease in carotid blood flow, and bilateral rSO2, and these outcomes became more pronounced towards the end of the surgery. Although there was a correlation between early POCD and a decrease in FV, there are many factors that might have affected POCD.

Keywords
Cerebral Perfusion, Thyroidectomy, General Anesthesia, Cognition

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Introduction

In order to perform surgical procedures more comfortably, the positions given according to the region and type of the operations might cause physiological changes. During thyroid surgery, the semi-Fowler position is defined as a body position at 30° head-of-bed elevation, with the extension of the head and neck in order to reach the mass comfortably. In this position, the main carotid arteries may be exposed to compression as a result of hyperextension of the head and the retraction of the thyroid. In addition to the effect of the position, when vasodilation caused by general anesthesia is added, cerebral hypotension might occur and consequently, cerebral blood flow, cerebral oxygen saturation and cognitive functions might be affected [1,2].

Doppler ultrasonography (USG) is a reliable, non-invasive imaging method used in the examination of carotid arteries with 92.6% sensitivity and 97% specificity [3].

Cerebral oximetry helps predict the cerebral oxygen delivery/consumption ratio in the frontal cortex, a hypoxemia-prone area named the "watershed zone", which is supplied by the anterior and middle cerebral arteries of the brain. Low intraoperative cerebral oxygen saturation (rSO2) values are reported to be associated with postoperative cognitive dysfunction (POCD) [4,5]. POCD is a common complication after anesthesia and surgery.

We aimed to observe the changes in main carotid artery blood flow measured with Doppler USG and cerebral oxygenation measured with NIRS during head positioning in thyroidectomy and related early and late effects on cognitive functions.

Material and Methods

Study Design and Ethical Consideration

This prospective and observational study (ClinicalTrials.gov: NCT04830293) was carried out in Zonguldak Bulent Ecevit University Hospital, from June 2019 to April 2020 after its approval by the Ethics Committee (Meeting Protocol No. 2019-40-14/02, Date: Feb 14, 2019) and obtaining written consent from the patients. It was conducted with 40 patients who were in the ASA I-II risk group and between the ages of 18-50, who were going to have a total thyroidectomy under general anesthesia. Those with a preoperative standardised mini-mental test (SMMT) [6] score below 23, hemoglobin below 8 g/dl, with a diagnosis of hypertension, hyperlipidemia, pregnancy, diabetes mellitus, cerebrovascular insufficiency, known carotid artery lesion, metabolic diseases, presence of any intracranial pathology, and surgeries exceeding 180 minutes were excluded. In addition to standard monitoring, bispectral index monitoring and bilateral rSO2 monitoring were performed using NIRS technology (O3 TM, Masimo, Irvine, USA). A decrease of more than 20% in rSO2 values compared to the initial value was accepted as intraoperative cerebral desaturation [7], and any decrease in such nature was recorded. After preoxygenation, routine anesthesia induction and maintenance were provided. Hemodynamic data of the patients -such as heart rate (HR), mean arterial pressure (MAP), bilateral rSO2 values and % change were measured at specific time intervals (T0: Before the induction of the anesthesia, T1: 10 minutes post-induction, T2: After positioning for the surgery, T3: 30 minutes post-induction, T4: 60 minutes post-induction, T5: 90 minutes post-induction, T6: 120 minutes post-induction, T7: 150 minutes post-induction, T8: Before the correction of the surgical position). Carotid diameter, PSV, EDV, mean flow velocity, AH, and RI were measured Using doppler USG and recorded for both sides at T0, T2, and T8. The cognitive functions of the patients were evaluated by applying SMMT 24 hours before the operation, at the postoperative 24th hour (early period), and 3 months later (late period). A decrease of ≥2 points compared to the baseline postoperative SMMT score was evaluated as a decrease in cognitive function.

Statistical Analysis

The necessary sample size was calculated using PASS (Power Analysis and Sample Size) 11 software before starting the study. The minimum number of patients to be reached was calculated as 31 as a result of the sample size analysis performed with reference to a 95% confidence interval (CI) and 95% power [8]. Considering a failure rate of 20%-25%, the required sample size was determined as 40 participants. The research data were analyzed using SPSS v.22.0 software. The Shapiro-Wilk was used as the normal distribution test. T-Test, Mann-Whitney U test, Friedman test, Repeated measures ANOVA, Spearman's correlation analysis, Pearson's correlation analysis, and ROC analysis were used during the analyses. A $p < 0.05$ value was considered statistically significant. Descriptive statistics were presented as Mean±SD, median, minimum, maximum, and the reference data as n and %.

Results

A total of 40 patients were included in the study. Table 1 presents the sociodemographic characteristics and the surgery and anesthesia times of the patients.

There was a significant difference between the HR, MAP and SpO2 values measured prior to and at certain times during the operation ($p < 0.001$). All measurements were within normal limits. When rSO2 values measured before and at certain times of the operation were examined, it was observed that there was an increase in rSO2 values 10 minutes after induction and a decrease at other times compared to the preoperative time, and there was a significant difference between intraoperative times ($p < 0.001$). Figure 1 presents the distribution of right and left rSO2 values measured before and at certain times of the operation.

The carotid diameter measured at T0 was significantly higher

Table 1. Sociodemographic Characteristics and Surgery/Anesthesia Times

Characteristics	n (%)
Gender M/F	6 (15.0) / 34 (85.0)
ASA I/II	5 (12.5) / 35 (87.5)
	Mean±SD
Age (years)	40.2 ±9.4
BMI (kg/m^2)	28.2±5.7
Anesthesia time (minutes)	162.9±26.2
Operation time (minutes)	149.4±28.1

M/F: Male/Female, BMI: Body Mass Index, SD: Standard Deviation

Table 2. Comparison of the % change rates of early and late POCD and the carotid artery doppler usg parameters

	Early Period POCD $^{+}$	Early Period POCD $^{-}$	p	Late Period POCD $^{+}$	Late Period POCD $^{-}$	p
	Mean±SD	Mean±SD		Mean±SD	Mean±SD	
Diameter(cm)	18.2±1.1	18.5 ±1.09	0.935	17±10.5	19.1±11.1	0.587
Volume of Blood flow (mL/min)	52.4± 20.2	37.2±21.5	0.019	47.5±22	42.9±22.3	0.546
Peak Systolic Velocity (cm/sec)	19.7±14.1	16.6±13.6	0.469	16.1±13.4	19.1±14	0.538
End Diastolic Velocity (cm/sec)	32.4±16.4	25.6±18.3	0.228	33.7±19	26.4±16.7	0.225
Mean velocity (cm/sec)	30.7±20	29.5±24.6	0.649	34.6±19.9	27.9±23.4	0.240
Resistance Index	7.1±6.7	6.5±5.3	0.957	8.2±7.8	6.1±4.9	0.798

SD: Standard deviation, cm: centimeters, mL: milliliters, min: minutes, sec: seconds.

Table 3. Validity of the values of flow volume

Change % Cut-off value	Sensitivity	Specificity	LR^{+}
20.77	94.7	33.3	1.41
28.50	84.2	47.6	1.60
53.50	73.7	76.2	3.09
61.25	31.6	81.0	1.66
70.05	21.1	95.2	4.39

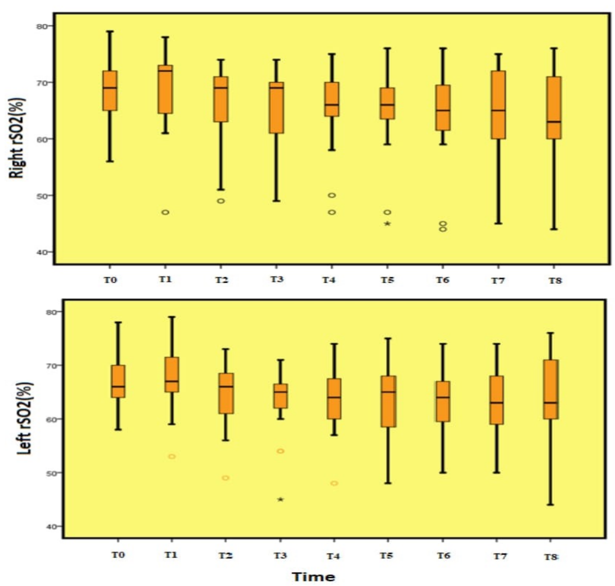

Figure 1. The distribution of Right and Left rSO2 values over time (box-plot graph)

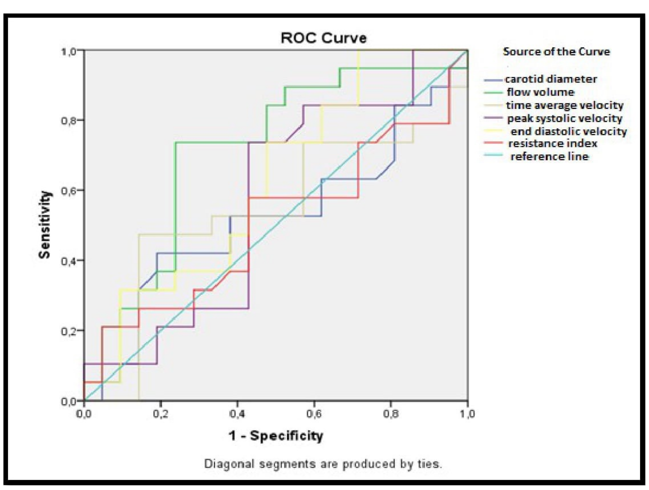

Figure 2. Early cognitive impairment - areas under the curve

than the values measured at T2 and T8 (p<0.05). The blood-flow volume, PSV, and EDV values at T8 were significantly lower when compared to the value at T0 (p <0.001, p = 0.043, p = 0.001, respectively). In contrast to other findings, pre-induction RI was significantly lower than after the surgical positioning (p = 0.004) and before the correction (p = 0.001).

The early POCD incidence was 47.5% (n = 19), and the late POCD incidence was 32.5% (n = 13). When preoperative, postoperative 24th-hour, and postoperative 3rd-month SMMT values were compared, there was a significant difference (p <0.001). Considering the post-hoc comparisons of the SMMT results, it was found that the preoperative SMMT value was significantly higher than the postoperative 24th-hour and postoperative 3rd-month results (p <0.001), and the 3rd-month was significantly higher than the postoperative 24th-hour value (p = 0.003).

In this study, the incidence of cerebral desaturation was 15% (n = 6). There was no significant correlation between cerebral desaturation and early and late POCD (p = 0.619, p = 0.351, respectively). There was also no significant correlation between anesthesia and the duration of surgery and early and late POCD. When early POCD and carotid artery Doppler measurement parameters were examined, there was a correlation between the decrease in carotid artery blood-flow volume and early POCD (p <0.05), while there was no significant relationship between late POCD and measurement parameters (Table 2).

Considering the possibility of using Doppler measurements for diagnostic purposes in early POCD, the % of the reduction in carotid artery blood flow volume was determined to be significant. The decision-making power of carotid artery blood flow volume as a diagnostic test was moderate (AUC = 0.717). Figure 2 presents the early impairment ROC analysis areas under the curve.

Table 3 presents the valid values for different cut-off values in terms of carotid artery blood flow volume change. The sensitivity was 73.7% and the specificity was 76.2% for a 53.5% change.

Discussion

In this study, we considered the effects of head and neck extension on carotid artery blood flow, rSO2 and POCD during thyroidectomy. A significant reduction in carotid blood flow and cerebral oxygenation was observed towards the end of the thyroidectomy. Decrease in carotid artery flow volume was determined to correlate with early POCD. However, no relationship was observed between POCD and cerebral desaturation.

Among general surgery patients, those who have undergone neck surgery are at higher risk of cerebrovascular events. These events might appear due to surgical and anesthetic maneuvers. In addition to surgical maneuvers, this increased risk may also be associated with the increased risk of surgical procedures requiring neck hyperextension. Hyperextension may lead to an intimal tear in the carotid artery, thrombus formation, or plaque ulcer caused by turbulent blood flow [9,10].

Especially the middle cerebral artery is an important vessel for cerebral blood flow. Therefore, stretching or narrowing of the carotid and vertebral artery leads to a greatly reduced flow in the middle cerebral artery, globally causing impaired brain perfusion. Siwac et al. [11] evaluated the blood flow changes in cerebral arteries in different head positions and stated that the blood flow velocity in cerebral arteries decreases, although not significantly, while the head and neck are in extension.

In another study, intraoperative rotation and/or extension of the cervical spine was demonstrated to cause a decrease in the mean blood flow rate of the middle cerebral artery by more than 20%, compared to the basal value [12]. Saraçoğlu ve ark. [8] showed that PSV, mean velocity, and blood flow volume in the common carotid artery were found to be significantly decreased compared to the initial values in their study on the effect of cervical extension on cerebral blood flow changes.

In this study, at the end of the operation, common carotid artery diameter, PSV, blood flow volume, and EDV decreased significantly compared to baseline values, while RI increased significantly. Approximately, there was a 9% decrease in PSV, an 18% decrease in EDV, a 35% decrease in flow volume, and a 5% increase in RI, compared to base values. We believe that these changes may have resulted from the mechanical stress caused by the head and neck position to the artery and the impact of general anesthesia on blood pressure, heart rate, cardiac output, peripheral vascular resistance, and arterial compliance.

Postural changes during anesthesia have a complex impact on systemic and cerebral circulation, potentially reducing cerebral blood flow and oxygenation [2]. One of the methods to monitor cerebral perfusion is cerebral oximetry. The normal rSO2 range in unconscious patients is 60%-75% [13]. There are reports that with an increase in cerebral desaturation over 20% compared to the base value in conscious patients, clinical symptoms of presyncope occur, and the highest cerebral desaturation value is 13% in those who do not develop syncope [14]. In this study, a decrease of 20% from the initial value lasting more than 15 seconds was accepted as cerebral desaturation.

Smarius et al. [15] showed that there was a severe cerebral desaturation lasting at least 3 minutes, less than 45%, rare, unilateral due to excessive stretching of the neck as a result of hyperextension applied to the head and neck during cleft palate surgery. They emphasized that there were no neurological sequelae postoperatively in any patients. Although there is no data for rSO2 values on cerebral desaturation threshold, which is severe enough to cause brain damage, animal studies suggest that values below 60% may be associated with medium risk and below 45% with a high risk of damage [16]. Although the definition of cerebral desaturation has changed in studies, the incidence of cerebral desaturation in the sitting position is reported to be between 0-80% [17,18]. Yaman et al. [19] emphasized that there was a significant decrease in cerebral oxygenation after the head and neck position given for thyroid surgery, and no serious cerebral desaturation was observed during the operation. In this study, the incidence of cerebral desaturation was found to be 15%. In this study, there was an increase in rSO2 values after induction, compared to the baseline value. During monitoring, the right and left rSO2 values tended to decrease, the lowest rSO2 values were at the end of the operation, just before the position was corrected, and they were above 60%. We believe that the reason for the increase in rSO2 values after induction is associated with the decrease in cerebral metabolism and oxygen demand due to the anesthetics, and the tendency of intraoperative rSO2 values to decrease results from the decrease in carotid blood flow volume due to the position. The reason for the absence of severe desaturation may be due to the possibility that autoregulation may have continued cerebral blood perfusion with the intracerebral collateral flow, even if the carotid blood flow decreased since the ASA I-II patient groups were included in the study.

Kim et al. [20] evaluated cerebral oxygenation in the beach-chair position and showed that the decrease in hemodynamic data, especially in MAP, was correlated with the decrease in rSO2. In our study, among 6 patients, one-time decreases of 20%-23% in rSO2 values were observed for less than 20 seconds, compared to baseline values. In all 6 patients, MAP was between 50-53 mmHg when rSO2 decreased. To increase cerebral rSO2, oxygen delivery to the brain should be increased. For this purpose, an increase PaCO2, hemoglobin, and/or cardiac output should be considered. To increase MAP, 5 mg of ephedrine hydrochloride was administered iv, since the PVI, BIS, and EtCO2 values were within the normal range. An increase in rSO2 values was observed after ephedrine. Although continuous monitoring of cerebral oxygenation provides interventions to maintain adequate cerebral oxygenation by monitoring rSO2, it is unclear from neuropsychological results whether interventions can improve POCD. Aguirre et al. [21] stated that hypotension in the first five minutes intraoperatively was more pronounced among patients with neurobehavioral disorders than those without. In our study, the relationship between cerebral desaturation and POCD could not be demonstrated. Biedler et al. [22] reported that 25.8% of patients with POCD in the first week, while this rate decreased to 9.9% in the third month. They stated that while older age, longer anesthesia time, low education level, second operation, postoperative infections, and respiratory complications were risk factors for early POCD, only advanced age was the risk factor for late stage POCD. Endocrine disorders and cognitive functions are also linked to each other. In the case of hypothyroidism, in which thyroid hormones are less secreted, slowing of all cognitive functions and distraction might be present [23-25]. However, it is not possible to demonstrate the results as we did not evaluate postoperative thyroid functions in the study There were no participants with advanced age in this study, and the incidence of early POCD was 47.5% and late POCD was 32.5%. It is a possible that the differences in incidence were due to the application of SMMT at different postoperative times, the age distribution, characteristics of the patient population, and the different types of operations they underwent.

Study Limitations

The first limitation of this study is that the postoperative thyroid functions were not evaluated. The second limitation is that the effect of the patient's position during the operation on cerebral hemodynamics and cognitive function among high-risk patients could not be evaluated.

Conclusion

It was observed that the head position caused a decrease in carotid artery diameter, blood flow velocity and flow volume, and cerebral rSO2. Although it was found that early POCD is correlated with the decrease in carotid artery flow volume, there are many factors that may affect POCD, so other factors need to be investigated. We believe that further studies will prove very useful to demonstrate the effect of head and neck position on carotid artery blood flow, cerebral oxygenation, and POCD, especially for advanced age and high-risk patients with vertebrobasilar insufficiency or intracranial pathologies.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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