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Original Article

# Effects of Head Position on Cerebral Oxygenation and Blood Flow Velocity During Thyroidectomy

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Abstract

**Objective:** Determining the blood flow through intra and extra-cranial arteries during neck extension may be helpful but is a controversial issue. We aimed to elucidate the changes in cerebral blood flow related to head positioning during thyroid surgery by carotid Doppler examination and regional oxygen saturation variations.

**Methods:** Thirty patients were recruited to the study. Patients were positioned with a final position of thyroidectomy consisting a 30° semi Fowler with the extension of neck and head. Values of peak systolic velocity, average velocity, arterial diameter and blood flow volume of the common carotid artery were calculated. Bilateral regional cerebral oxygen saturation were monitored continuously.

**Results:** At the end of the operation, peak systolic velocity, average velocity and blood flowvolume of the common carotid artery decreased significantly compared to the baseline measurement ($p<0.001$). Both left and right cerebral oximetry measurements showed a significant increase after induction and the increased oxymetric values persisted at the end of the operation ($p<0.001$). Age, body mass index, surgical duration and anaesthesia duration were found not to be correlated with the changes occurred in the values of peak systolic velocity, average velocity, arterial diameter, blood flow volume of the common carotid artery, left and right regional cerebral oxygen saturation after induction and at the end of surgery.

**Conclusion:** The head and neck extension given for thyroidectomy negatively affect carotid blood flow and cerebral oxygenation gradually and become pronounced especially at the end of surgery. In conclusion, it is important to maintain the cerebral perfusion pressure and cerebral blood flow.

**Keywords:** Thyroidectomy, cerebral oxygenation, blood flow

## Introduction

Positioning of the head and neck during general anaesthesia is a method performed at varying rates and degrees depending on the type and needs of a surgical procedure. It has been reported that carotid, vertebral artery occlusion and dissection and middle cerebral artery infarction may develop due to head rotation or extension (1). Cervical spine rotation or flexion is not adequately avoided in some surgical procedures, including thyroidectomy, shoulder surgery or carotid endarterectomy (2).

When blood flow decreases in one or more arteries, compensatory blood flow is generally provided with intracerebral collateral circulation. However, if congenital abnormalities or diseases such as atherosclerosis occur in patients requiring excessive head rotation or extension, intraoperative cerebral ischaemia may be seen due to secondary collateral flow insufficiencies.

The situation may worsen in the case of a sustained intraoperative hypotension. Determining the blood flow through intra- and extra-cranial arteries during neck extension may be helpful, but this is a controversial issue. There are published studies reporting that no significant change was found in carotid and vertebral artery blood flow as a result of neck extension or rotation (3, 4). In a systemic review, it was concluded that in 4 of 7 studies, cervical arterial blood flow did not show a significant decrease following different neck positions. By contrast, 3 other studies demonstrated a significant decrease in collateral vertebral artery flow (5). Recent studies have analysed the effects of cervical movements on vertebral artery and carotid artery blood flow, but the results regarding this matter are also debatable (6, 7).



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Regional cerebral oxygen saturation determined using near-infrared spectroscopy provides useful information about brain tissue oxygenation and is used to monitor cerebral ischaemia in different clinical situations (8). As far as it is known, there are no studies in the literature analysing both the carotid artery by Doppler examination and the regional cerebral oxygenation level in patients having thyroidectomy in a semi-Fowler and head-extension position.

The primary objective of this study is to elucidate the changes in carotid artery blood flow related to head positioning during thyroid surgery by Doppler examination. The secondary objective is to determine if those changes have actual cerebral metabolic effects as reflected by regional oxygen saturation variations.

## Methods

Following the approval of the Ethics Committee from the Istanbul University Istanbul School of Medicine, 30 patients were recruited after signing written informed consent forms. The study population was composed of patients 18-50 of age who were scheduled to have total thyroidectomy under general anaesthesia due to thyroid cancer, Hashimoto's thyroiditis or thyrotoxicosis. The exclusion criteria were haemoglobin level under 8 g $dL^{-1}$, hypertension, hyperlipidaemia, diabetes mellitus, cerebrovascular insufficiency, metabolic diseases or any intracranial pathology.

Euthyroidism was restored in all patients during the preoperative period. At arrival to the operating room, standard monitoring was carried out by using a 3-lead electrocardiogram, peripheral oxygen saturation and non-invasive blood pressure. Infusion of a balanced electrolyte solution was started via a 20 G IV line. The cerebral oximeter (INVOS, Somanetics Corporation, Troy, MI, USA) sensor was bilaterally placed on the forehead of the patient according to the operating manual and continuous measurement was commenced.

After resting in a supine position for 10 minutes, baseline values were taken, including heart rate (HR), mean arterial pressure (MAP), peripheral and cerebral regional oxygen saturation ($SpO_2$, $rSO_2$) and carotid Doppler measurement.

After completion of the baseline assessment, the induction of general anaesthesia was performed with IV propofol 2-3 mg $kg^{-1}$, rocuronium 0.6 mg $kg^{-1}$ and fentanyl 2 µg $kg^{-1}$. Maintenance of anaesthesia was carried out using 6% desflurane in 40% oxygen with 60% nitrous oxide. Following that, patients were positioned at a 30° semi-Fowler position with extension of the neck and head.

Measurements were repeated twice more after positioning: post-induction and at the end of the operation before the thyroidectomy position was neutralised. All examinations were carried out by the same anesthetist. The head was rotated 10° to the collateral side during Doppler measurements.

The Doppler examination was performed at the common carotid artery level 2.0 cm proximal to the left bifurcation valve through a GE Logiq Book XP Doppler Ultrasonography (GE Medical Systems, China) and a linear probe (8L, 6.0-9.0 MHz, GE Parallel Design, Phoenix). For accurate results, the arterial diameter was measured with magnified B-mode images.

Measurements were carried out on the intraluminal vertical plane between the echogenic intimal layers. Values of peak systolic velocity (PV), average velocity (TAMEAN), arterial diameter (D) and blood flow volume of the common carotid artery (Vol) were calculated. Bilateral regional cerebral oxygen saturation was monitored continuously and recorded at the same intervals with other measurements.

**Statistical analysis**

We calculated that the study sample size would require approximately 30 patients to detect a 10 cm $sec^{-1}$ difference between the groups in regard to mean velocity with $\alpha$ level of 0.05, standardised effect size of 0.83 and a power of 90%.

The Statistical Package for the Social Sciences 20.0 (IBM SPSS Statistics; Armonk, NY, USA) was used for analyses. The average, standard deviation, ratio and frequency values were used for descriptive statistics while data distribution was examined using the Kolmogorov-Smirnov test and ANOVA were used for the analysis of quantitative data. The post-hoc analysis was done by Tukey's test with the Bonferroni modification.

Correlation was analysed with the Pearson correlation test. A p value <0.05 was considered significant.

## Results

Two patients were excluded from the study because surgical durations were longer than expected. The data of 28 subjects were analysed. Demographic data is presented in Table 1 together with the length of surgery and anaesthesia. Although no significant change in the heart rate after induction was observed, a significant decrease in mean arterial pressure was observed compared to the baseline value. At the end of the operation, heart rate and blood pressure showed a significant decrease compared to the baseline values (Table 2, p<0.05).

The evaluation of the Doppler data revealed that the carotid diameter showed no difference after induction compared to baseline values; however, significant changes were noted at the end of the operation compared to both the preoperative and postinduction periods. At the end of the operation, PV, TAMEAN and Vol decreased significantly compared to the baseline measurement (Table 3, p<0.001).

Compared to the baseline values, both left and right cerebral oximetry measurements showed a significant increase after induction, and the increased oximetry values persisted at the end of the operation (p<0.001). However, those values de-

Table 1. Patient characteristics, duration of surgery and anaesthesia (mean±SD)

| | | Minimum | Maximum | n | % |
|---|---|---|---|---|---|
| Age (year) | | 18 | 50 | 39.1±9.8 | |
| Sex | Female | | | 22 | 79% |
| | Male | | | 6 | 21% |
| Body mass index (kg/m²) | | 20 | 34 | 26.9±3.9 | |
| Duration of anaesthesia (min) | | 60 | 170 | 96.3±35.6 | |
| Duration of surgery (min) | | 50 | 180 | 111.6±38.3 | |

SD: standard deviation

Table 2. The change in blood pressure and heart rate compared to the preoperative period (mean±SD)

| | | Current value | The change compared to preoperative period | p |
|---|---|---|---|---|
| Mean arterial Pressure (mmHg) | Baseline | 97.54±12.29 | | |
| | Post-induction | 87.75±18.28 | -9.79±15.26 | 0.002 |
| | End of surgery | 77.71±8.67 | -19.82±13.60 | <0.001 |
| Heart rate (beat/min) | Baseline | 89.14±14.51 | | |
| | Post-induction | 88.68±12.51 | -0.46±14.46 | 0.866 |
| | End of surgery | 71.43±10.85 | -17.71±14.30 | <0.001 |

SD: standard deviation

Table 3. Values of peak systolic velocity, average velocity, arterial diameter, volume of blood flow of the common carotid artery (mL/min)

| | Baseline | Post-induction | End of surgery |
|---|---|---|---|
| Diameter (cm) | 0.70±0.13 | 0.69±0.13 | 0.64±0.1* |
| Peak velocity (cm/sec) | 26.34±10.05 | 27.94±9.9 | 21.41±10.28* |
| Mean velocity (cm/sec) | 21.14±4.92 | 22.48±5.46 | 16.42±3.99* |
| Volume of blood flow (mL/min) | 431±118 | 495±128 | 277±88* |

*p<0.001, compared to the baseline measurement

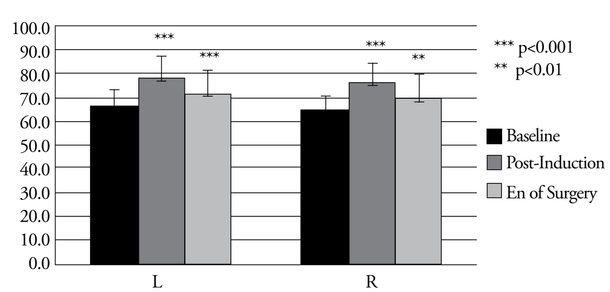


Figure 1. Cerebral pulse oximeter values
ANOVA test

creased significantly at the end of the operation compared to the post-induction values (Figure 1, p<0.01).

Age, body mass index, surgical duration and anaesthesia duration were not found to be correlated with the changes that occurred in the values of PV, TAMEAN, D, Vol and left and right regional cerebral oxygen saturation after induction and at the end of surgery in comparison with the baseline values (Table 4, p>0.05). However, the change in the mean arterial pressure after induction, in comparison to the preoperative period, had a significant negative correlation with the changes in the D value after induction, considering the baseline measurement (Figure 2, $r^2$=0.178, p<0.05). There was a significant positive correlation between the changes in $SpO_2$ and TAMEAN values at the end of surgery compared to the preoperative period (Figure 3, $r^2$=0.185, p<0.05).

## Discussion

In the present study, we examined the effects of cervical extension performed on the patients having a thyroidectomy operation. Not only the blood flow, volume and mean velocity, but also the regional cerebral saturation was adversely affected during the position for thyroidectomy. Moreover, they slightly increased. However, at the end of the surgery, a significant decrease was obtained in these values according to baseline measurements. The Doppler ultrasound used for

Table 4. The correlation of hemodynamics and peripheral oxygen saturation with the changes after induction and after surgery in comparison to the preoperative period

| | | Changes compared to preoperative period | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Vel | | Mean | | D | | Vol | | L | | R | |
| | | $T_1$ | $T_2$ | $T_1$ | $T_2$ | $T_1$ | $T_2$ | $T_1$ | $T_2$ | $T_1$ | $T_2$ | $T_1$ | $T_2$ |
| Mean arterial pressure (mmHg) | r | 0.189 | -0.047 | -0.232 | 0.100 | -0.422 | -0.185 | -0.194 | 0.007 | -0.206 | -0.200 | -0.032 | -0.229 |
| | p | 0.335 | 0.811 | 0.235 | 0.613 | 0.025 | 0.346 | 0.323 | 0.973 | 0.293 | 0.308 | 0.870 | 0.240 |
| Heart rate (beat $min^{-1}$) | r | 0.168 | -0.053 | -0.248 | 0.153 | -0.006 | 0.011 | -0.223 | -0.005 | -0.024 | -0.084 | 0.078 | -0.003 |
| | p | 0.392 | 0.790 | 0.204 | 0.436 | 0.975 | 0.957 | 0.253 | 0.981 | 0.902 | 0.670 | 0.692 | 0.988 |
| $SpO_2$ (%) | r | 0.241 | -0.312 | -0.171 | -0.431 | -0.236 | -0.135 | -0.051 | -0.197 | 0.223 | 0.152 | -0.040 | -0.027 |
| | p | 0.216 | 0.106 | 0.385 | 0.022 | 0.227 | 0.493 | 0.796 | 0.315 | 0.254 | 0.439 | 0.838 | 0.890 |

Vel: velocity; Mean: average velocity; D: diameter; Vol: blood flow; L: left cerebral pulse oximeter; R: right cerebral pulse oximeter; SPO2: peripheral oxygen saturation; $T_1$: after induction; $T_2$: at the end of surgery

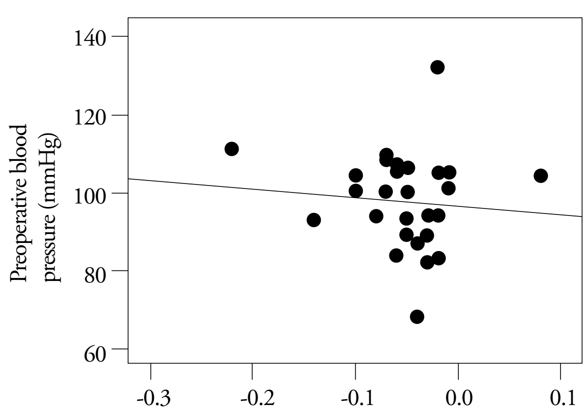


Figure 2. The correlation between the changes in the blood pressure and carotid artery diameter after induction in comparison to the preoperative period

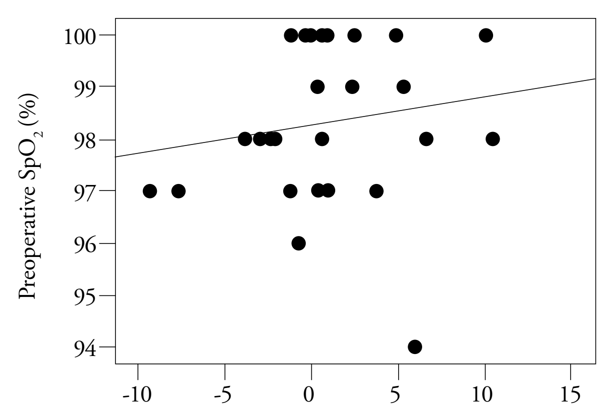


Figure 3. The correlation between the changes in $SpO_2$ and TAMEAN values at the end of surgery compared to the preoperative period

measuring blood flow through the common carotid artery is considered to be reliable in this respect (2). The carotid arterial diameter measurements were performed by the same anesthesiologist using the same technique. The Doppler data of the carotid diameter did not show any difference. However, there was a decrease in carotid flow rate. The most probable reason for this factor was thought to be a decrease in mean arterial pressure because of a reduction in systemic vascular resistance following general anaesthesia.

When compared with the baseline cerebral oxygen saturation values, there was a significant increase in post-induction and end of surgery values despite the decrease in blood flow, as shown by the Doppler measurements.

We can conclude that the cerebral oxygenation is maintained and the most probable explanation for this phenomenon is the decrease in the metabolic rate of brain and oxygen consumption due to general anaesthesia.

The present study analysed the data of the patients who were under the age of 50 and free of systemic hypertension, hyperlipidaemia, diabetes mellitus, cerebrovascular insufficiency, vertebrobasilar failure, metabolic diseases or any intracranial pathology. Interestingly, about 35% decrease in cerebral blood flow did not result in any undesired consequences such as cerebral desaturation. However, this magnitude of decrease in blood flow may lead to serious complications in elderly patients with hyperlipidaemia, vertebrobasilar failure or carotid plaques, so this should be taken into consideration. Although general anaesthetics are known to have neuro-protective effects, specified cautions must be taken into consideration in high-risk surgical patients to protect the central nervous system (9). Both propofol and volatile anaesthetics have neuro-protective effects against the damage that may develop as a result of cerebral ischaemia (5). These factors should be considered while deciding the type of anaesthesia used for high-risk patients; and the clinical effects of anesthetics can be assessed by regional cerebral oxygen saturation. Nevertheless, anaesthetists should allow only a moderate neck extension in such high-risk patients. Studies examining the effects of neck and head extensions, specifically where hypotensive anaesthesia is administered, can be planned, especially for specific surgical procedures where both head extension and controlled-hypotension are simultaneously applied.

No correlation was found between the decrease in blood pressure, cerebral oxygenation and change in the carotid blood flow. Therefore, we may conclude that the changes in blood flow happened due to the head positioning instead of blood pressure changes. Because higher arterial blood flow is required in order to ensure adequate cerebral perfusion in anaemic patients due to the compromised oxygen-carrying capacity, these patients were excluded from the study.

Intraoperative arrhythmias may also lead to cerebral hypoxaemia by reducing cerebral blood flow due to blood loss, thromboembolism, low cardiac output and low haematocrit (2). In the present study, researchers did not come across complications that might have led to such disorders during the preoperative period.

The study indicated that, compared to the baseline measurement, there was a 35% decrease in carotid blood flow at the end of surgery. This clinically significant decrease may have led to cerebral ischaemia by reducing cerebral blood flow. However, the absolute thresholds that may result in cerebral ischemic events have not established at this point.

One limitation of the study is that patients were not assessed for any cognitive decline in the post-operative period. If such tests had been performed, we would have obtained a better understanding of potential clinical consequences of such decreases in cerebral blood flow.

The circle of Willis is a structure that ensures the continuity of cerebral blood flow and sustains the flow through two different lines, namely anterior and posterior arteries (10). Measurement of cerebral blood flow can be assessed by transcranial Doppler measurements of both anterior and posterior cerebral circulation. The benefit of transcranial Doppler in this regard has been proven (11, 12). The present study was designed by accepting the cerebral blood flow of the patients as normal and considering that both anterior and posterior blood supply of the brain was natural. In other words, this study was planned for the patients who were assumed to have normal posterior cerebral blood flow. In this study, we only concentrated on the anterior cerebral circulation assessments.

## Conclusion

The head and neck positioning given for thyroidectomy surgery negatively affects carotid blood flow, and this decrease in flow may become more pronounced at the end of the surgery.

Preventing patients from secondary brain damage that may develop due to positioning is the combined responsibility of anaesthesiologists, surgeons and circulating nurses. Therefore, it is important to maintain cerebral perfusion pressure and cerebral blood flow.

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**Ethics Committee Approval:** Ethics committee approval was received for this study from the ethics committee of İstanbul University İstanbul School of Medicine.

**Informed Consent:** Written informed consent was obtained from patients who participated in this study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept - A.S., E.Ç.; Design - A.S., D.A., A.Y.; Supervision - E.Ç.; Resources - A.S., A.Y., E.Ç.; Materials - D.A., E.Ç.; Data Collection and/or Processing - A.S., D.A., I.C.S.; Analysis and/or Interpretation - A.S.; Literature Search - A.S., N.A., E.Ç.; Writing Manuscript - A.S., D.A.; Critical Review - E.Ç.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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