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Effect of Head Position on Cerebral Oxygen Saturation in Tympanoplasties Performed with Controlled Hypotensive Anesthesia

Kontrollü Hipotansif Anestezi ile Yapılan Timpanoplastilerde Baş Pozisyonunun Serebral Oksijen Saturasyonu Üzerine Etkisi

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ABSTRACT

Objective: Our goal was to examine the impact of head position, which had not been examined before, on cerebral oxygenation in tympanoplasties performed in the reverse Trendelenburg position during controlled hypotension.

Methods: This prospective study was conducted in our clinic between July 2020 and November 2020. A total of 81 patients aged 18-59 years, who had an ASA physical condition classification score of 1-2 and were evaluated in two groups according to the type of surgery. In the tympanoplasty group, the head was turned to the contralateral ear and placed in minimal extension while in the septoplasty group, the head was kept in the neutral position. The regional cerebral oxygen saturation (c-rSO2) values of the right and left sides were recorded continuously with O_3 regional oximetry probes on both sides throughout the operation.

Results: When an overall examination was performed without separating the tympanoplasty group as right/left, the median oxygen saturation level was 69.50% (Q1:61.00-Q3:72.00) for the operated side and 74.00% (Q1:66.00-Q3:79.00) for the contralateral side. The oxygen saturation of the operated side was statistically significant lower (p<0.001). The median oxygen saturation of the operated side in the tympanoplasty group [69.50% (Q1: 61.00-Q3:72.00)] was statistically significantly lower than that of the septoplasty group [72.00% (Q1:65.25-Q3:77.75)] (p=0.004).

Conclusion: This study showed that the rotation of the head 45° or above in the revers Trendelenburg supine position causes cerebral desaturation on the opposite side of rotation.

Keywords: Anesthesia, blood pressure, ear, intracranial hypotension, otologic surgical procedures

ÖZ

Amaç: Timpanoplastilerde ters trendelenburg pozisyonunda ve kontrollü hipotansiyon etkisi altındaki hastalarda daha önce araştırılmamış olan, baş pozisyonunun serebral oksijenizasyon üzerindeki etkilerinin araştırılması amaçlanmıştır.

Yöntem: Bu prospektif çalışma Temmuz 2020-Kasım 2020 tarihleri arasında kliniğimizde gerçekleştirildi. Yaşları 18-59 arasında ASA fiziksel durum sınıflaması skoru 1-2 olan ve ameliyat tipine göre iki grupta değerlendirilen toplam 81 hasta çalışmaya dahil edildi. Timpanoplasti grubunda baş karşı kulağa çevrilerek minimal ekstansiyonda yerleştirilirken, septoplasti grubunda baş nötral pozisyonda tutuldu. Sağ ve sol taraf bölgesel serebral oksijen saturasyonu (c-rSO2) değerleri operasyon boyunca her iki tarafta O_3 bölgesel oksimetre probları ile sürekli olarak kaydedildi.

Bulgular: Timpanoplasti grubu sağ/sol olarak ayrılmadan genel bir inceleme yapıldığında ameliyat edilen taraf için medyan oksijen satürasyon düzeyi %69,50 (Q1:61,00-Q3:72,00), karşı taraf içinse %74,00 (Q1:66,00-Q3:79,00) idi. Ameliyat edilen tarafın oksijen satürasyonu istatistiksel olarak anlamlı derecede düşüktü (p<0,001). Timpanoplasti grubunda ameliyat edilen tarafın medyan oksijen satürasyonu [%69,50 (Q1:61,00-Q3:72,00)] septoplasti grubuna göre [%72,00 (Q1:65,25-Q3:77,75)] istatistiksel olarak anlamlı derecede düşüktü (p=0,004).

Sonuç: Bu çalışma, sırtüstü yatar ters Trendelenburg pozisyonunda başın 45° veya daha fazla rotasyonunun, rotasyonun karşı tarafında serebral desatürasyona neden olduğunu göstermiştir.

Anahtar sözcükler: Anestezi, kan basıncı, kulak, intrakranial hipotansiyon, otolojik cerrahi prosedürler

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INTRODUCTION

In tympanoplasty, exposure, one of the most important technical challenges during operation, requires the rotation of the neck to provide a better viewing angle. This problem arises from the anatomical localization of the ear. In ear surgery, the use of both hands in the microscopic method, and the endoscope and surgical instrument entering the surgical area in the endoscopic method, in addition to the limited surgical area caused by the structure of the external auditory canal, generate visual field issues. This is further complicated by bleeding, which is the most important rate limiting step for surgeons in ear surgery, paving the way for complications. Controlled hypotensive anesthesia and reverse Trendelenburg positioning are among the recommended methods to reduce bleeding and improve surgical field visualization (1,2). In a previous study on hypotensive anesthesia, systolic blood pressure was kept between 80 and 90 mmHg and the mean arterial blood pressure (MABP) between 50 and 60 mmHg to reduce bleeding in the surgical area and improve visualization (1). However, this situation has raised concerns about brain damage caused by hypotensive anesthesia (3). It has not been studied how head rotation affects cerebral oxygenation during ear surgery in patients who are both in the reverse Trendelenburg position and under the influence of controlled hypotension. It makes sense to monitor the oxygenation of the central nervous system as a target of anesthetic drugs to avoid the adverse effects of hypotensive anesthesia (4). Regional oximetry is a non-invasive method for evaluating cerebral oxygenation and is often used for perioperative hemodynamic management targeting adequate cerebral perfusion and oxygenation (5-8). On the other hand, it is important to determine whether hemispherical oxygen saturation changes in ear surgery where the head and neck are rotated.

In this study, we aimed to reveal whether the oxygen saturation of the brain changed due to the head rotation in reverse Trendelenburg position.

MATERIAL and METHODS

This prospective randomized controlled study was conducted in our clinic between July 2020 and November 2020. Ethical approval for this study (approval number HRU/20.13.24) was provided by the Ethical Committee of Harran University Clinical Research (13.07.2020, HRU/20.13.24). A total of 81 patients aged 18-59 years, who had an ASA physical condition classification score of I and II were scheduled to undergo tympanoplasty or septoplasty were evaluated in two groups according to the type of surgery. All patients were verbally informed about the content of consent form, and their written consent was obtained.

Patients who received endoscopic transcanal type 1 tympanoplasty procedures with the head rotated 45° or more, a surgical duration of less than one hour, and no bleeding greater than 50 mL were included in the tympanoplasty group. The septoplasty group consisted of cases in which this surgery was performed due to isolated septal deformity, it took less than one hour, there was less than 50 mL bleeding, and the neutral head position was maintained during surgery. Both groups were selected from patients with natural carotid-vertebral artery Doppler ultrasonography (USG) images.

Patients with uncontrolled chronic diseases such as cerebrovascular disease, systemic vascular disease, central nervous system disease, congestive heart failure, liver disease, kidney disease, diabetes mellitus, or hypertension, those with a history of alcohol or drug addiction or allergy to anesthetic drugs, and cases in which surgery lasted longer than one hour were excluded from the study. Carotid and vertebral artery Doppler USG was performed in all patients one day before the operation. Patients with pathologies that could prevent blood flow to the brain (calcific plaque, aneurysm, etc.) were also excluded from the study.

The patients were taken to the operating room without any premedication and monitored using standard 3-lead electrocardiography (ECG), non-invasive arterial blood pressure and peripheral oxygen saturation (SaO_2) measurements, and O_3 regional oximetry. The O_3 regional oximetry probe (Masimo Corporation, Irvine, CA) was placed on the right and left sides of the patient's forehead before anesthesia induction to record regional cerebral oxygen saturation (c-rSO_2). The placement of the two probes on the right and left sides of the forehead was undertaken by the surgeon in the same way in all patients to prevent possible errors. The values taken from the probe were recorded using the O_3 module patch cable and root monitor (Masimo corporation, Irvine, CA). While the patient was breathing room air before anesthesia induction, the c-rSO_2 values recorded from the right and left O_3 regional oximetry probes were accepted as the initial values. In all patients, anesthesia was induced with the intravenous (iv) administration of 2 mg kg^{-1} propofol, 1 µg kg^{-1} fentanyl and 0.6 mg kg^{-1} rocuronium. Following endotracheal intubation, all patients in both groups were mechanically ventilated with the Dräger Primus (Dräger Medical, Lübeck, Germany) anesthesia device, and then the operating table was moved to the reverse Trendelenburg position of approximately 20° to minimize the amount of bleeding. Anesthesia was maintained using 2 L min^{-1} fresh gas flow and 50% O_2/air gas mixture and sevoflurane at a minimal alveolar concentration of 1 and iv 0.25 µg kg^{-1} min^{-1} remifentanil infusion. The respiration rate was set to meet 30 to 35 mmHg end-tidal carbon dioxide ($EtCO_2$). In the tympanoplasty group, the head was turned to the contralateral ear and placed in minimal extension while in the septoplasty group, the head was kept in the neutral position.

The c-rSO_2 values of the right and left sides were recorded continuously with O_3 regional oximetry probes on both sides throughout the operation. The c-rSO_2 values recorded immediately after the end of the surgical procedure were accepted as the final values. The mean c-rSO_2 value was also calculated from the device's continuous recordings. Continuously measured heart rate (HR), MABP, SaO_2 and $EtCO_2$ values measured during the time of intubation were recorded every five minutes during the operation, and the mean values were calculated using the recorded values.

In order to provide controlled hypotension in all groups, taking into account the basal values recorded before anesthesia induction, a loading dose of 1 µg kg^{-1} remifentanil was administered iv over 30 seconds, followed by 0.25 µg kg^{-1} min^{-1} infusion. The drug dosages were adjusted to achieve a perioperative MABP that was 20% lower than the initial measurement (>55 mmHg). Remifentanil infusion was lowered and iv ephedrine (5–10 mg) was administered when needed if MABP dropped to less than 80% of its baseline or if MABP was less than 55 mmHg. When MABP increased above 20% of the baseline value, remifentanil infusion was gradually increased and iv nitroglycerine (5 µg min^{-1}) infusion was initiated in required patients. A decrease in HR below 50 beats min^{-1} was defined as bradycardia and was treated with 0.5 mg iv atropine.

All patients received iv 1 mg kg^{-1} tramadol for postoperative pain control. Peripheral oxygen saturation was kept as 99 ± 1% throughout the operation in all patients. The time for each patient to reach a modified Aldrete score of 9 from the end of surgery was recorded in the recovery unit by a technician unaware of the patient groups and the study.

Statistical Analysis

Data analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) Statistics v. 17.0 (IBM Corporation, Armonk, NY, USA) software package. The Kolmogorov-Smirnov test was used to examine whether the distribution of continuous numerical variables was close to normal, and Levene's test was conducted to test whether the assumption of the homogeneity of variances was met. Descriptive statistics were expressed as mean ± standard deviation or median (25^{th}-75^{th} percentile) for continuous numerical variables and number and percentage of cases for categorical variables. The significance of the difference between the groups in terms of the mean values was examined with Student's t test and that of the differences in terms of continuous numerical variables where the assumptions of parametric test statistics were not provided was evaluated with the Mann-Whitney U test. The $\chi 2$ test with continuity correction was undertaken for the analysis of categorical data. The Wilcoxon sign test was conducted to examine the significance of the differences in terms of changes in brain oxygen saturation levels according to localization and time within the groups. Whether there was a statistically significant correlation between continuous numerical variables was investigated with Spearman's rank-order correlation test. Unless otherwise stated, results where the p value was<0.05 were considered statistically significant. However, Bonferroni's correction was also made to control type I error in all possible multiple comparisons.

RESULTS

The demographic and clinical characteristics of the study groups were given in Table I.

The measurements after administering remifentanil bolus and infusion in all groups are listed in Table II. For HR, MABP, and SaO_2 measurements, there was no statistically significant difference between the groups as compared to baseline, following induction, 10 min, 30 min, 60 min, 90 min, 120 min, and extubation.

Eight patients (20%) in the tympanoplasty group and six patients (14.6%) in the septoplasty group required anticholinergic medication (atropine) because they had bradycardia. Six patients (20%) in the septoplasty group and three patients (20%) in the tympanoplasty group required five milligrams of ephedrine each because of hypotension that they experienced after receiving remifentanil.

When an overall examination was performed without separating the tympanoplasty group as right/left, the median c-rSO_2 value was 69.50% (Q1: 61.00-Q3: 72.00) for the operated side and 74.00% (Q1: 66.00-Q3: 79.00) for the contralateral side, and c-rSO_2 of the operated side was statistically significant lower (p<0.001).

The median c-rSO_2 of the operated side in the tympanoplasty group [69.50% (Q1: 61.00-Q3: 72.00)] was statistically significantly lower than that of the septoplasty group [72.00% (Q1: 65.25-Q3: 77.75)] (p=0.004). However, there was no significant difference in the median c-rSO_2 values of the contralateral sides between the tympanoplasty group [74.00% (Q1: 66.00-Q3: 79.00)] and the septoplasty group (p=0.478).

In the comparison of the median c-rSO_2 values of the operated sides between the two groups, the median c-rSO_2 value was statistically significantly lower among the patients undergoing right ear surgery in the group compared to that of the right hemisphere in the septoplasty group (p=0.008). The mean c-rSO_2 value of the patients undergoing left ear tympanoplasty was also lower compared to that of the left hemisphere in the septoplasty group, but the difference was not statistically significant (p=0.109) (Table III).

In the tympanoplasty group, the initial and final c-rSO_2s were statistically similar both on the operated side (p=0.729) and on the contralateral side (p=0.189). There was no statistically significant difference between the operated and contralateral sides in terms of initial and final c-rSO_2s (p=0.758 and p=0.171, respectively) (Table IV).

In the septoplasty group, the initial and final c-rSO_2s were statistically similar for both the right hemisphere (p=0.581) and the left hemisphere (p=0.314). There was no statistically significant difference between the right and left sides in terms initial c-rSO_2 (p=0.604), but the final c-rSO_2 was statistically higher in the left hemisphere than in the right hemisphere (p=0.003) (Table V).

Table I: Demographic and Clinical Characteristics of the Study Groups

	Tympanoplasty (n=40)	Septoplasty (n=41)	p-value
Age (years)	32.6 ± 11.4	28.7 ± 6.1	0.063†
Gender			0.585‡
Male	21 (52.5%)	25 (61.0%)	
Female	19 (47.5%)	16 (39.0%)	
Body weight (kg)	70.6 ± 13.8	69.2 ± 9.8	0.599†
Height (m)	1.67 ± 0.093	1.67 ± 0.107	0.998†
Body mass index (kg m^{-2})	25.1 ± 3.8	24.9 ± 4.4	0.849†
Operation side			N/A
Right	24 (60.0%)	-	
Left	16 (40.0%)	-	
Time to achieve an Aldrete score of 9 (min)	9.5 (9.0-11.0)	13.0 (11.0-14.5)	**<0.001**¶

†: Student's t-test, **‡:** χ2 test with continuity correction, **¶:** Mann-Whitney U test, **N/A:** Not applicable, **kg:** Kilogram, **m:** Meter, **min:** Minute.

Table II: The Measurements After Administering Remifentanil Bolus and Infusion in All Groups

	T MABP	T HR	T SaO_2	S MABP	S HR	S SaO_2
Baseline	90.1	77.1	97.2	88.6	76.1	98.1
After induction	76.8	68.3	99.1	73.6	68.1	99.2
10.min	75.6	66.6	99.2	71.4	65.2	99.4
30.min	72.7	68.0	99.3	69.2	64.3	99.4
60.min	69.5	68.4	99.5	66.1	65.2	99.2
90.min	72.1	70.2	98.8	70.4	68.6	99.0
120.min	71.2	71.1	99.4	68.5	69.9	99.4
After extubation	92.2	81.2	98.8	91.3	80.4	97.6

T: Tympanoplasty group, **S:** Septoplasty group, **MABP:** Mean arterial blood pressure, **HR:** Heart rate, **SaO_2:** Peripheral oxygen saturation.

Table III: Mean Brain Oxygen Saturation Levels of the Patients During the Operation according to Study Group and Operation Side

	n	Right hemisphere	Left hemisphere	p-value†
Tympanoplasty				
Right ear operated	24	68.00 (61.00-71.00)	71.00 (64.40-78.75)	**<0.001**
Left ear operated	16	74.50 (69.25-79.75)	70.50 (63.00-72.75)	**0.004**
Septoplasty	41	72.00 (64.50-78.00)	73.00 (66.00-78.50)	0.022
p value ‡		**0.008**	0.109	

Descriptive statistics given as median (25^{th}-75^{th} percentile) values. **†:** Comparison between the right and left hemispheres within the groups, Wilcoxon's signed rank test, statistically significant at p<0.0167 according to the Bonferroni correction. **‡:** Comparison of the operated side in the tympanoplasty group with the corresponding side of the septoplasty group, Mann-Whitney U test, statistically significant at p<0.0125 according to the Bonferroni correction.

Table IV: Initial and Final Brain Oxygen Saturation Levels of the Operated and Contralateral Sides in the Tympanoplasty Group

	Initial	Final	p value†¶
Operated side	71.00 (62.25-75.75)	70.00 (66.25-75.75)	0.729
Contralateral side	71.00 (67.00-75.00)	71.00 (66.50-79.00)	0.189
p-value ‡¶	0.758	0.171	

Descriptive statistics given as median (25th-75th percentile) values. **†:** Comparison between the initial and final measurements on the same side; Wilcoxon's signed-rank test. **‡:** Comparison between the operated and contralateral sides for the same monitoring time; Mann-Whitney U test. **¶:** Statistically significant at p<0.0125 according to the Bonferroni correction.

Table V: Initial and Final Brain Oxygen Saturation Levels of the Septoplasty Group according to Hemisphere

	Initial	Final	p-value†¶
Right hemisphere	73.00 (67.00-75.00)	70.00 (67.00-78.50)	0.581
Left hemisphere	72.00 (67.50-76.00)	72.00 (68.00-79.00)	0.314
p value‡¶	0.604	**0.003**	

Descriptive statistics given as median (25th-75th percentile) values. **†:** Comparison between the initial and final measurements on the same side; Wilcoxon's signed-rank test. **‡:** Comparison between the hemispheres for the same monitoring time; Mann-Whitney U test. **¶:** Statistically significant at p<0.0125 according to the Bonferroni correction.

In the tympanoplasty group, no statistically significant correlation was found between the median c-rSO_2 of the operated side and age (p=0.554) and body mass index (BMI) (p=0.538). There was also no statistically significant correlation between the median c-rSO_2 of the contralateral side and age and BMI (p=0.755 and p=0.728, respectively). Lastly, within the tympanoplasty group, no statistically significant difference was observed in the median c-rSO_2 values of the operated and contralateral sides according to gender (p=0.178 and p=0.226, respectively).

DISCUSSION

Although controlled hypotensive anesthesia is very useful in surgically controlling the surgical field, reports show that it causes ischemic damage (9). Cerebral oxygenation was previously evaluated in patients who underwent endoscopic sinus surgery (ESS) with hypotensive anesthesia (8,10). In these studies, no adverse situation was observed in cerebral oxygen saturations, and as a result it was stated that cerebral oxygenation could be kept in a safe range in hypotensive anesthesia. However, to our knowledge, no study has been conducted to investigate the effect of hypotensive anesthesia and the reverse Trendelenburg position or that of head rotation on cerebral oxygen saturation in ear surgery.

Some studies in the literature concluded that neck rotation and/or extension causes a change in blood flow in adults (11). In addition, the reverse hyperextension of the head in cleft palate surgery and tonsillectomy in children was observed to significantly reduce cerebral tissue oxygenation. However, the disadvantage of that study was that there was no control group to compare the results (12). Therefore, in our study, as a control group, we also had the septoplasty group in which the head is kept in the neutral position when performing ear surgery. Liao et al. showed that in preterm babies placed in the supine position for surgery, turning the head from the midline to the side caused a significant decrease in cerebral tissue oxygen saturation (13). In another study, normal physiological lateral rotational head and neck movements do not produce any significant blood flow changes in the afferent cerebral arteries of healthy adults (14). We believe that head rotation at physiological limits will not impair cerebral oxygenation at the rotation side in adults, consistent with the aforementioned study. We think that the high mean cerebral oxygen saturation value of the contralateral hemisphere in ear operations shortens the time to reach the Aldrete score 9' statistically significantly compared to the control group. However, it is obvious that further studies are needed to make an objective interpretation of this difference. In our study, we think that the lower cerebral oxygen saturation in the operation side hemisphere is related to the higher level of that hemisphere compared to the heart level. Also, the low cerebral oxygenation on the reverse side of the rotation compared to the neutral position supports this finding. At this point, we think that these values should be interpreted together with cerebral hemodynamics in order to make a more objective interpretation. We plan to strengthen our results in our future studies by interpreting these values together with the MABP, $EtCO_2$ values. There is no study in the literature on the effects of head rotation in the reverse Trendelenburg position on cerebral oxygenation. We think that continuous cerebral oxygen monitoring with O_3 regional oximetry will be beneficial especially in ear tumor surgeries because of the high probability of bleeding. Although we cannot directly compare our results with another study at this point, we think that the finding of low cerebral oxygenation on the opposite side of the head rotation is a striking finding.

In prospective observational studies, it has been shown that cerebral desaturation events are associated with postoperative neurological dysfunction after cardiac surgery and thoracic surgery (15,16). There are no human studies on the time and saturation thresholds determined for cerebral desaturation to cause brain damage. In the literature, the most widely accepted view is that the absolute value of c-rSO_2 falling below 40 or decreasing by more than 25% compared to the baseline value is associated with neurological dysfunction (12,17,18). In line with this information, in our study, we considered the critical threshold values for c-rSO_2 as below 50 or a decrease of more than 20% compared to the baseline value. The regulation of cerebral oxygen saturation is essentially a condition that depends on cerebral blood flow. Cerebral blood flow is regulated by partial carbon monoxide ($PaCO_2$) pressure rather than arterial $PaCO_2$ pressure (19). Because, 75% of the blood amount in the vascular structures of the human brain consists of venous circulation and 25% of arterial circulation (20). In previous studies, for SaO_2, a threshold value of 85% in infants and 90% in adults was accepted to indicate the development of hypoxia in the brain vascular bed (18,21,22). However, it has been reported that even if SaO_2 is within the normal range, there may be a decrease of more than 20% in cerebral oxygen saturation during controlled hypotension (17). In our study, we ensured that the peripheral SaO_2 value was maintained at 90% and above. However, while pulse oximetry measures arterial oxygen saturation in peripheral blood, O_3 regional oximetry predominantly measures venous oxygen saturations in cerebral circulation. Therefore, in cases of hypoxia, c-rSO_2 falls earlier than SaO_2, but this decrease is slower. Lu et al. proved this by showing a difference of approximately 40 seconds between the two (18). Since the brain is very sensitive to oxygen saturation, it can quickly react to changes in saturation. The first change occurs in the direction of increasing blood flow to the brain. This delay can be explained based on vascular vasodilation due to hypoxia in the brain occurring before peripheral vasodilation (23).

It is possible to state that there are contradictory statements on this subject in the literature. Some studies have reported that there is no correlation between c-rSO_2 and other intraoperatively monitored parameters such as MABP, SaO_2, and $EtCO_2$ (24). In contrast, in another study conducted with ESS patients, it was emphasized that although controlled hypotensive anesthesia alone was a risk for cerebral desaturation, there was no risk of cerebral desaturation if MAP was >55 mmHg, $EtCO_2$ was 30-40, and the head was kept in the neutral position(8). Heller et al. found a direct relationship between SaO_2 and $EtCO_2$ and c-rSO_2 in ESS cases in which they applied controlled hypotension, but the authors did not show a relationship between MAP and c-rSO_2 (10). Similarly, the operation time did not have a statistically significant effect on cerebral hypoxia, but it was emphasized that the amount of blood loss was significantly effective (24). We consider that the non-significant effect of the operation time was due to the prone positioning of the patients and the neutral positioning of the head throughout the operation. In spinal surgery, it has been shown that c-rSO_2 is severely affected by any head position other than the neutral position, such as rotation, flexion and extension movements (25). Since an increase in the amount of bleeding decreases the total blood amount in the vascular bed and result in a decrease in the oxyhemoglobin level, this also has a negative effect on c-rSO_2. In our study, we demonstrated the effect of head rotation only by obtaining results independent of the effect of other factors since we kept the operation time under one hour and excluded patients with a bleeding of more than 50 mL.

In line with recent studies, we believe that surgical comfort can be enhanced by controlled hypotension (26,27). However, we suggest that the patient should be closely monitored, and that this method should be chosen in appropriate cases due to the lengthy recovery period following controlled hypotension along with issues like bradycardia that may arise during the operation (26). Controlled hypotension is a procedure that requires close monitoring of the patient. The safety of controlled hypotension was the subject of a recent meta-analysis, which revealed no correlation between mortality rates with MABP less than 60 mmHg (28). Thus, when used appropriately, controlled hypotension is a reliable technique for procedures requiring minimal bleeding.

The most important limitation of our study is the lack of a neurological evaluation. Although the brain oxygen saturation values did not fall below the critical threshold, it would have been more beneficial to evaluate neurological impairment. In addition, the fact that c-rSO_2 values are not interpreted together with MABP and $EtCO_2$ can be considered as a limitation, we will plan our future studies by taking this into account.

CONCLUSION

This study showed that the rotation of the head 45° or above in the revers Trendelenburg supine position with controlled hypotensive anesthesia causes cerebral desaturation on the opposite side of rotation. However, although none of our patients exceeded the determined critical thresholds (c-rSO_2<50 or a >20% decrease compared to the baseline value), we observed marked and statistically significant desaturation values. Therefore, we consider that continuous cerebral oxygen monitoring with O_3 regional oximetry can be beneficial in all operations that involve head rotation. We further propose that controlled hypotension during surgery can improve surgical comfort.

AUTHOR CONTRIBUTIONS

Conception or design of the work: TU, AD, NB, TM
Data collection: TU, AD, NB, TM
Data analysis and interpretation: TU, AD, NB, TM
Drafting the article: TU, AD, NB, TM
Critical revision of the article: TU, AD, NB, TM
Other (study supervision, fundings, materials, etc): TU, AD, NB, TM
The author (TU, AD, NB, TM) reviewed the results and approved the final version of the manuscript.

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