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Evaluation of the effect of horizontal and oblique muscle surgery on choroidal thickness

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Abstract

Objective: To evaluate the changes in subfoveal choroidal thickness after horizontal and oblique muscle surgeries in patients with strabismus.

Materials and methods: Fifty-eight patients diagnosed with strabismus and had strabismus surgery between July 2018 to January 2019 were included in this retrospective study. Group 1 consists of patients underwent inferior oblique muscle recession surgery (n=18) and Group 2 consists of patients underwent horizontal rectus muscle surgery (n=40). The subfoveal choroidal thickness was measured using enhanced depth imaging optic coherence tomography preoperatively and first day and first month after surgery.

Results: In Group 1, a significant increase was observed in choroidal thickness on postoperative first day compared to baseline values ($p<0.05$). When preoperative and postoperative first month measurements were compared, an insignificant increase was observed in Group 1 ($p>0.05$). In group 2, there was an increase in choroidal thickness on first day and the first month postoperatively, but no significant difference was found compared to preoperative choroidal thickness values.

Conclusion: Our study showed that subfoveal choroidal thickness increases in the early period after horizontal and oblique muscle surgeries. We speculate that these changes may be due to the inflammation caused by surgical trauma and the altered choroidal microcirculation.

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Introduction

Surgical correction of strabismus addresses functional and aesthetic concerns associated with conditions like misaligned eyes, abnormal head posture, and nystagmus. The goal of the intervention is to restore proper coordination of the eyes, crate binocular single vision, and prevent ambliyopia (1). Surgical correction demonstrably improves patients' quality of life by positively impacting both their social and psychological well-being (2).

All ocular surgeries carry risks of complications and may cause functional and structural changes. In the literature, complications such as intraocular pressure changes, cystoid macular edema, and alterations in anterior chamber volume and ocular blood flow have been reported after strabismus surgery (3,4).

The seven extraocular muscles, responsible for directing the globe's movement, exhibit varied points of insertion within the sclera. Tractions during the exploration and release of extraocular muscles may have potentially harmful effects on the macula and the choroid (5). The choroid serves as the primary source of nutrients and oxygen for the retinal pigment epithelium and outer retina, playing a crucial role in maintaining their metabolic and functional integrity. The choroid is the sole source of metabolic exchange for the avascular fovea (6). Theoretically, muscle trauma during an operation and muscle suturing can potentially result in changes to the blood flow in the choroid. Changes in choroidal blood flow may play a role in various retinal and optic nerve diseases (7). Choroidal thickness (CT) varies by sex, age, refractive status, axial length, and circadian rhythm (8,9). Previous investigations have conclusively documented dynamic alterations in choroidal thickness in the course of specific ophthalmic pathologies (10). There is no accurate information describing the effect of extraocular muscle surgery on the CT.

This study employed enhanced depth imaging optical coherence tomography (EDI-OCT) to investigate subfoveal choroidal thickness (CT) changes following horizontal and oblique strabismus muscle surgeries.

Materials and methods

This study was conducted in accordance with ethical principles outlined in a relevant international declaration. Ethical approval was obtained from Saglik Bilimler University Hamidiye Medical Research Ethical Committee, Turkey (Date: 13.02.2023 Approval number: 2/10).. All patients (or their legal guardians) provided informed consent following relevant ethical guidelines. The study recruited patients diagnosed with strabismus who underwent surgery from July 2018 to January 2019.

Fifty-eight patients were included. Those patients with histories of diabetic retinopathy, central serous chorioretinopathy, glaucoma, contact lens use, keratoconus, neurologic disease, nystagmus, ocular surgery or ocular trauma, chronic systemic disease, and vascular abnormalities detected during ophthalmological examinations were not included. In addition, the patients who could not cooperate with EDI-OCT scanning and the scans with signal-to-noise ratio under 20 dB were excluded from the study.

During the preoperative routine examination, cycloplegic refraction was performed, enabling the prescription of precise refractive corrections for patients. All patients underwent thorough ophthalmologic examinations, encompassing measurements of aided and uncorrected visual acuity, cycloplegic refraction, detailed anterior segment assessment, and comprehensive dilated fundus examination. All follow-up examinations incorporated a comprehensive assessment of visual acuity, refraction, both near and distant deviation angles, and prism cover test evaluation to quantify the size of the deviation.

Two distinct patient groups were investigated in this study: Group 1 (n=18) underwent inferior oblique muscle recession surgery. In contrast, Group 2 (n=40) underwent horizontal rectus muscle recession surgery (lateral rectus or medial rectus). In both groups, only one muscle was intervened in each operation.

All surgical procedures were undertaken under general anesthesia. Access to the extraocular muscles was achieved through a limbal conjunctival incision. The muscles were identified using strabismus hooks. Extraocular muscle sutures were performed using 6-0 Vicryl suture, and conjunctival closure was carried out with 8-0 Vicryl. Postoperatively, all patients were prescribed steroid eye drops and topical antibiotics for 2 weeks.

Image acquisition and processing

Preoperative subfoveal CT measurements were obtained using EDI-OCT. These measurements were then repeated 1 day and 1 month postoperatively in patients undergoing strabismus surgery (Figure 1). Study participants underwent SD-OCT examination using the Spectralis device (Heidelberg Engineering Co, Germany) with the enhanced depth imaging (EDI) modality. All EDI-OCT measurements were acquired between 9:00 and 11:00 am to avoid diurnal fluctuations. Only images obtained between 9:00 and 11:00 am were included in the study. Pupils were dilated with tropicamide (Alcon, Denmark) before each examination. High-resolution imaging was achieved by acquiring seven sections, within a 5°–30° rectangular region centered on the fovea. CT was described as the distance measured between two distinct hyperreflective lines: Bruch's membrane (BM) and the inner scleral border. CT measurements were performed manually on the acquired SD-OCT images using the Heidelberg Eye Explorer software. Image acquisition was performed by a single trained technician. The measurements of CT were performed by two ophthalmologists independently for this study. The difference between the measurements of the two physicians was higher than 15% of the average, a senior ophthalmologist was consulted.

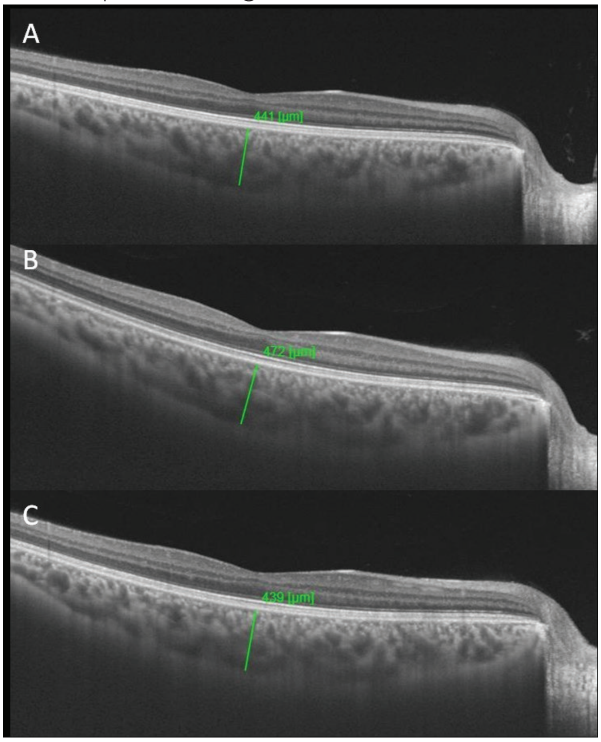

Figure 1: Preoperative (A) and postoperative 1st day (B) and 1st month (C) images of central foveal region-centered SFCT measurement in an 8-year-old patient

Statistical analysis

All analyses were performed using SPSS software version 20.0 (IBM SPSS Inc.). Categorical variables in the study were summarized using descriptive statistics: mean ± standard deviation (SD). The normality of the data was analyzed using Kolmogorov- Smirnov test. Non-parametric tests were performed when the data did not follow normal distribution. CT differences between preoperative and postoperative were evaluated by analysis of variance (ANOVA) in the operated eyes. In addition, CT differences within the groups were analyzed by the Mann-Whitney U test and ANOVA test. For pairwise comparisons, Friedman and Bonferroni were applied for Mann Whitney test and ANOVA test respectively, when significance was obtained. Statistical significance was described as a p-value < 0.05.

Results

Our study evaluated 67 patients aged 6 to 45 years (mean±SD, 23.07±11.66). Table 1 summarizes the preoperative characteristics of the patients. Nine patients were excluded due to specific eligibility criteria: two had previously undergone secondary strabismus surgery, three exhibited insufficient cooperation during the examination, and four had OCT image quality issues compromising data integrity. After these exclusions, 58 patients remained as the study participants.

The surgical procedure was well-tolerated, and no complications, such as fat prolapse, scleral perforation, or ocular hemorrhage, were reported during or after the operation. There were no significant changes compared to baseline values in unaided and aided visual acuity and refraction after surgery.

Preoperative subfoveal CT measurements averaged 366.45±79.83 µm. On the first postoperative day, this increased to 379.17±75.83 µm, followed by a slight decrease to 375.17±76.14 µm at one month postoperatively. Subfoveal CT measured on the first postoperative day was significantly greater than preoperative values ($p<0.05$). However, a comparison between preoperative and first-month postoperative CT measurements revealed no significant difference.

We compared the CT values preoperatively and postoperatively within and between groups. There was

Table 1: Preoperative characteristics of the patients

	Group 1 (n=18)	Group 2 (n=40)	p-value*
Age, years	17.29±7.65	25.91±14.62	0.061
Gender (Male/Female)	8/10	20/20	0.473
Spherical equivalent (D)	+0.94 ± 0.34 D	+0.87 ± 0.30 D	0.123
Axial length (mm)	25.33 ± 1.24	24.82 ± 1.35	0.311
Preoperative choroidal thickness (μm)	323.43±82.12	361.00±84.58	ü0.001

All data are represented by mean ± standard deviation. *Mann-Whitney U Test

Table 2: Preoperative and postoperative choroidal thickness measurement

	Preoperative	Postoperative day 1	Postoperative month 1	p-value
Operated eyes (n=58)	350.97±75.74	358.48±71.06	360.90±71.77	0.190*
Group 1 (n=18)	323.43±82.12	337.71±77.79	324.29±84.62	0.023$^{\beta}$
Group 2 (n=40)	361.00±84.58	371.27±79.53	368.64±78.62	0.114*
p-value	0.014$^{\alpha}$	0.020$^{\alpha}$	0.013$^{\alpha}$	

All data are represented by mean ± standard deviation. *ANOVA test, β Kruskal-Wallis Test, α Mann-Whitney U Test

a significant difference in CT measurements between Group 1 and Group 2 at all time points (Table 2). The number of participants was unequally distributed; therefore, the CT measurements were analyzed within groups.

In Group 1 preoperative median CT thickness was 320 μ (IQR:308-335). After surgery, the median CT measurement was 325 μ (IQR:309-348) and 326 (IQR:310-340) one day and one month after surgery, respectively (p=0.014, p=0.063 respectively). However, Group 1 exhibited a modest postoperative increase in mean choroidal thickness (CT), this change was not statistically significant compared to preoperative values.

In Group 2, there was an increase in CT measurements on the postoperative first day and postoperative first month after surgery compared to preoperative values (p=0.114, p=0.246, respectively), but the differences were statistically insignificant. Table II shows the preoperative and postoperative CT measurements.

Discussion

The choroidal layer supplies vascular support to the outer retina, providing oxygen and nourishment, clearing waste products, and contributing to the temperature regulation of the outer coats of the eyeball. Impaired choroidal circulation may disrupt the optic nerve, retinal nerve fiber layer, and photoreceptors (11).

Optic coherence tomography has gained popularity in imaging of the choroid in vivo. OCT is a non-invasive, rapid, and repeatable clinical tool in providing detailed anatomical information about the choroid with the provision of quantitative estimation (12).

This study purposed to delve into the impact of horizontal and oblique muscle surgeries on subfoveal CT in patients with strabismus. We observed a notable increase in CT on the first day after oblique muscle surgery; however, no significant change was noted in the CT in the postoperative first month.

The subfoveal CT increased after horizontal muscle surgery, however, the changes were insignificant. Alis et al. explored the impact of performing single versus double horizontal rectus muscle surgeries (recession ± resection) on subfoveal CT. They demonstrated that rectus muscle surgery led to an elevation in subfoveal CT on the first day and the first week postoperatively. They hypothesized that the observed increase in subfoveal CT could be attributable to altered choroidal microcirculation, potentially caused by mechanical traction and anterior ciliary artery injury during surgery (13). Moreover, Atalay et al. observed an elevation in CT following horizontal rectus muscle surgery; however, they observed no significant difference in subfoveal CT after oblique muscle surgery. Atalay et al. proposed that postoperative inflammation may contribute to increased CT (14). Inan et al. evaluated the effects of strabismus surgery on subfoveal CT using EDI-OCT (7). They proposed that strabismus surgery can decrease the CT up to the second postoperative week. After this period, they found no change between preoperative and postoperatively. The potential mechanism could involve an ischemic process triggered by vascular damage and vasoconstriction at the level of the choroid. Trauma of the muscles or muscle suturing during the operation may change the nutrition of choroidal tissue. Muscle resection has the potential to modify the blood flow in the posterior ciliary arteries. They proposed that during the acute phase, inadequate blood flow could result in a subsequent reduction in subfoveal CT (7). Consistent with their results, Yetkin et al observed a decrease in the CT during the early postoperative period in pediatric patients of double horizontal muscle surgery (15). In the postoperative third month, no significant change was found. They suggested almost the same mechanism as Inan et al. They suggested that the possible effect of the surgery is the activation of compensatory vasoconstrictor mechanisms due to damage to the choroidal vessels (7). This process can lead to ischemia during the early postoperative period. Also, they speculated that the compensatory mechanisms in the late postoperative period can return the CT to the preoperative values (15).

Our findings support the previously described postoperative inflammation, mechanical traction, and anterior ciliary artery injury theory. The effects of external traction and globe compression on the retina and choroid have not been well studied. Muscle traction and globe compression can lead to compression on the short posterior arteries and damage to the anterior ciliary artery. Also, previous studies have shown that venous drainage obstruction, which may be induced after scleral buckle surgery, may result in subfoveal choroidal thickening. Remodeling of the choroidal venous drainage can maintain the preoperative CT back by a decrease in blood flow.16 Isolating and hooking the inferior oblique muscle during surgery carries the potential risk of traction-induced injury at its insertion site. Besides, there is no accurate explanation about the choroidal thickening we can speculate that mechanical traction theory is eligible in Group 1.

Proinflammatory cytokines and prostaglandins can be released secondary to the traumatic intervention. Atalay et al claimed that the strabismus surgery can cause inflammatory cascades in the choroid (14). Inflammatory mediators are responsible for blood-retinal barrier breakdown. An increase in CT can be related to transient local inflammation (17). Kimura et al. assessed the subfoveal CT preoperatively and one week, one month, and three months following scleral buckling surgery. They reported a temporary increase in CT at 1 week postoperatively. The authors suggested that postoperative inflammation, in addition to the alteration in circulation, might also be an effective factor (16).

However, its retrospective nature, short follow-up period, and relatively small number of patients may be considered as the limitations of the current study. Owing to the short postoperative follow-up period we analyzed early effects of surgeries on CT. In addition, the study involved two surgical approaches, with comparable patient numbers in each group.

Conclusions

In conclusion, our study showed that subfoveal CT increases in the early postoperative days after horizontal and oblique muscle surgeries. After one month there was a slight increase in CT, but no significant change was found. We speculate that this difference may be attributed to inflammation induced by surgical trauma, mechanical traction, and altered choroidal microcirculation. To definitively ascertain the long-term effects of strabismus surgery on CT, it is essential to conduct further studies with a prospective design, incorporating larger sample sizes and extending follow-up periods.

Conflict of interest: All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

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Contributions

Research concept and design: ZH, MO

Data analysis and interpretation: ZH, MO

Collection and/or assembly of data: ZH, MO

Writing the article: ZH, MO

Critical revision of the article: ZH, MO

Final approval of the article: ZH, MO

All authors read and approved the final version of the manuscript.

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