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ORIGINAL PAPER

Choroidal thickness in macular holes

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Abstract
Purpose To determine the association between choroidal thickness (CT) and anatomic success in closed and open macular holes (MHs) following surgery.
Methods One hundred and thirty-six eyes of 136 patients who underwent surgery due to primary MH were included in this study. Choroidal thickness was measured from various points (subfoveal, temporal, nasal, superior and inferior 1500 μm from the center of the fovea) in both eyes with MH and fellow eyes. We determined associations among the duration of symptoms, MH dimensions and CTs from various points with anatomic success and correlations between CT and MH dimensions and duration of symptoms.
Results Choroidal thickness was significantly lower in eyes with MH than fellow eyes in both open and closed MHs. Base diameter [$p = 0.025$, odds ratio (OR) = 0.428], minimum hole diameter ($p = 0.030$, OR = 0.211) and duration of symptoms [$p = 0.034$, OR = 0.443] were significantly associated with anatomic success. However, CTs from various points were not associated with anatomic success despite a significant preoperative subfoveal CT difference between open and closed MHs (198 ± 21 μm in open MHs and 230 ± 30 μm in closed MHs; $p < 0.001$). Preoperative subfoveal CT was moderately correlated with base diameter ($r = -0.505$, $p < 0.001$), minimum hole diameter ($r = -0.518$, $p < 0.001$) and duration of symptoms ($r = -0.510$, $p < 0.001$).
Conclusions Failed MHs were associated with larger hole dimensions (base diameter and minimum hole diameter) and longer duration of symptoms. Preoperative subfoveal CT was thinner in open MHs, but there was no association with anatomic success. Choroidal thinning may be linked to larger and chronic MHs.

Keywords Macular hole · Choroidal thickness · Anatomic success · Macular hole dimensions

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Introduction

Macular hole (MH) formation was proposed by Gass as anteroposterior and tangential vitreal traction on the foveal area, which has been demonstrated in optical coherence tomography (OCT) [1, 2]. Pars plana vitrectomy (PPV) and internal limiting membrane (ILM) peeling which removes the anteroposterior and tangential traction, become the standard surgical treatment in these cases [3, 4]. However, MH can develop in the absence of vitreomacular tractional forces such as in complete posterior vitreous detachment or vitrectomized eyes [5, 6]. Cystoid macular edema, progressive outer retinal degeneration, epiretinal membrane formation and choroidal thinning have been suggested to be other preceding conditions. [6, 7].

Aras et al. [7] found a reduction in foveal choroidal blood flow, and, Zhang et al. [8] found decreased foveal choroidal thickness (CT) with enhanced depth image (EDI) OCT in cases of MH, and they concluded that CT may play a role in the pathogenesis of MH. The choroid is an important metabolic supplier for the fovea. Therefore, reduction in the choroidal blood flow may alter the healing process and contribute to failed MH closure. On the other hand, choroidal thinning may be thought a marker of MH characteristics such as chronicity and hole dimensions which have been demonstrated to be the predictors of anatomic outcomes of surgery [9–14], because decreased foveal choroidal blood flow may be a consequence of the loss of overlying retinal tissue, which has been strongly suggested to control choroidal blood flow [15].

The aim of this study was to evaluate and compare MH characteristics (MH dimensions and duration of symptoms) and preoperative CTs between closed and open MHs and to determine whether there was a relationship among CT, anatomic success and MH characteristics.

Methods

We retrospectively reviewed the records of patients who underwent surgical intervention for the treatment of primary idiopathic MH between 2014 and 2017 at the Gazi University Faculty of Medicine (Ankara, Turkey). The study was approved by the Ethics Committee and adhered to the tenets of the Declaration of Helsinki.

All of the patients applied to hospital due to loss of their vision. Patients who had MH due to other etiologies (e.g., myopia, trauma, cystoid macular edema), patients with ocular pathologies such as diabetic retinopathy or retinal vascular diseases, patients with previous ocular surgery history, hyperopia or myopia greater than 1 diopter, axial length lower than 22 mm or greater than 24 mm or systemic diseases that may have effected the measurements, were excluded from the study.

Surgical procedure

After the entrance of transvitreal 23 gauge vitreoretinal instruments, core vitrectomy was completed. The posterior hyaloid was stained with triamcinolone and separated and cleaned using ocutome probe. The ILM was stained using brilliant blue dye and peeled with ILM forceps up to the arcuates. After fluid air exchange, a 23 gauge, silicone-tipped cannula was placed over the MH without touching the retinal pigment epithelium to drain the remaining fluid. The air was changed to gas (20% sulphur hexafluoride) endotamponade. The patients were asked to take facedown positioning for 1 week.

The preoperative hole base diameter, the minimum hole diameter and duration of the symptoms were evaluated and determined as MH characteristics. Preoperative and postoperative (1 month after surgery) OCT measurements were performed using Spectralis (Heidelberg Engineering, Heidelberg, Germany) OCT. The EDI mode of Spectralis was performed for the CT measurements. The CT estimations were performed by two independent expert OCT readers who were not involved in the data analysis. The estimations of the readers were compared and averaged for the analysis. The CT was defined as the distance between the retinal pigment epithelium line (the outermost hyperreflective line) and the choroidoscleral boundaries. The subfoveal, inferior, superior, nasal and temporal thickness 1500 μm away from the fovea were measured. Patients who were examined between 9 AM and 12 PM were included in the study to avoid the effects of diurnal variation. To adjust for potential compounding factors, age, sex, refraction and axial length (AL) matched patients were included in this study.

Statistical analysis was performed using SPSS version 16 (SPSS, Chicago, IL,USA). An independent *t* test was used to compare the continuous data including the duration of symptoms, the mean hole base diameter, the mean minimum hole diameter and preoperative CTs between closed and open MHs. A paired *t*-test was used to compare CTs between eyes with MH and fellow eyes. Continuous data, which were statistically significant in independent *t*-test, were included in a multilogistic regression model to better delineate the association of these data with anatomic success. Furthermore, Pearson's correlation test was to investigate correlations between the duration of symptoms, MH dimensions (mean hole base and minimum hole diameter) and CTs in all patients. A p value less than 0.05 was considered to indicate statistical significance.

Results

There were 254 eyes of 254 patients who underwent surgical intervention for the treatment of idiopathic MH between 2014 and 2017. In total, 230 eyes (90.5%) underwent a successful MH surgery. One hundred and thirty-six eyes of 136 patients who satisfied the inclusion criteria were included in this study. Mean age was 65.4 ± 3.4 years (range 60–69) in open MHs and 65.3 ± 3 years (range 60–69) in closed MHs ($p = 0.907$). All of the patients underwent a standard surgical procedure (PPV, large ILM peeling, gas (20% sulphur hexafluoride) endotamponade and facedown positioning). There were 36 men (26.5%) and 100 women (73.5%). The MH remained open in 16 eyes (11.7%) and closed in 120 eyes (88.3%). Thirty-three of 36 men (91.7%) and 87 of 100 women (87%) had anatomic success following surgery ($p = 0.559$). Duration of symptoms, mean hole base diameter and minimum hole diameter were significantly higher in open MHs than closed MHs (Table 1). The mean CTs of the fellow eyes were significantly higher than eyes with MHs in both open and closed MHs (Table 2). In open MHs, the preoperative subfoveal CT and CT at the temporal 1500 µm from the center of the macula were significantly lower than closed MHs (Table 3). The mean AL was 23.03 ± 0.6 mm (range 22–24 mm) in open MHs and 23.2 ± 0.58 mm (range 22–24 mm) in closed MHs; the difference was not statistically significant ($p = 0.331$).

Based on the multilogistic regression analysis, the duration of symptoms, mean hole base diameter and mean minimum hole diameter were significantly associated with anatomic success (Table 4). There was a moderate correlation between subfoveal CT and duration of symptoms and macular hole dimensions (mean hole base and minimum hole diameter) (Table 5).

Discussion

The closing mechanisms of MHs are not yet fully understood. Therefore, some preoperative parameters were used to predict the closure of the MHs. Chronicity, minimal hole diameter and hole base diameter are the most commonly used parameters to predict anatomic success [9, 10]. Our findings were consistent with the literature that open MHs had significantly larger dimensions and longer duration of symptoms than closed MHs.

Vitreomacular tractional forces are not thought to be the sole factor in the pathogenesis of MH. Alteration in choroidal layer has been suggested to be a possible contributing factor to the pathogenesis of MH. Aras et al. [7] found a decreased choroidal blood

Table 1 Duration of symptoms, mean base and minimum hole diameter in open and closed MHs

Parameter	Open		Closed		p value
	Average ± SD	Range	Average ± SD	Range	
Duration of symptoms (months)	9.4 ± 3.2	5–15	5.4 ± 2	2–12	< 0.001
Base diameter (µ)	1237 ± 185	725–1441	864 ± 225	426–1542	< 0.001
Minimum diameter(µ)	539 ± 135	265–800	327 ± 107	140–655	< 0.001

MH macular hole

Table 2 Mean CTs of the eyes with MHs and fellow eyes

Mean choroidal thickness (μm)	Open MH			Closed MH		
	Eyes with MH Average ± SD (range)	Fellow eye Average ± SD (range)	*p* value	Eyes with MH Average ± SD (range)	Fellow eye Average ± SD (range)	*p* value
Subfoveal	198 ± 21 μm (165–233)	242 ± 22 μm (220–295)	< 0.001	230 ± 30 (145–300)	251 ± 17 (220–300)	< 0.001
Temporal 1500	206 ± 21 (169–240)	240 ± 13 (220–260)	< 0.001	227 ± 36 (137–323)	251 ± 19 (230–300)	< 0.001
Nasal 1500	179 ± 40 (128–254)	210 ± 29 (170–253)	< 0.001	195 ± 36 (100–290)	215 ± 21 (172–272)	< 0.001
Superior 1500	224 ± 35 (175–281)	253 ± 30 (210–300)	< 0.001	234 ± 37 (120–320)	260 ± 26 (198–305)	< 0.001
Inferior 1500	211 ± 46 (151–281)	241 ± 36 (181–290)	< 0.001	220 ± 39	242 ± 24 (195–280)	< 0.001

CT choroidal thickness, *MH* macular hole

Table 3 Mean CTs and axial lengths in closed and open MHs

Mean choroidal thickness (μ)	Open		Closed		*p* value
	Average ± SD	Range	Average ± SD	Range	
Subfoveal	198 ± 21	165–233	230 ± 30	145–300	**< 0.001**
Temporal 1500 μ	206 ± 21	169–240	227 ± 36	137–323	**0.026**
Nasal 1500 μ	179 ± 40	128–254	195 ± 36	100–290	0.146
Superior 1500 μ	224 ± 35	175–281	234 ± 37	120–320	0.351
Inferior 1500 μ	211 ± 46	151–281	220 ± 39	131–320	0.438
Axial length	23.1 ± 5.7	22–24	23.3 ± 5.6	22–24	0.657

Subfoveal and temporal CTs were significantly lower in open MHs than closed MHs are given in bold

CT choroidal thickness, *MH* macular hole

Table 4 Multivariate logistic regression analysis of factors associated with anatomic success

	Odds ratio	*p* value
Subfoveal CT	1.892	0.186
Temporal 1500 μ CT	0.522	0.079
Minimum hole diameter	**0.211**	**0.030**
Hole base diameter	**0.428**	**0.025**
Duration of symptoms	**0.443**	**0.034**

MHs with larger dimensions and longer duration significantly associated with anatomic success are given in bold

flow in eyes with MH, and other authors such as Xu et al. [16], Reibaldi et al. [17] and Zeng et al. [18] found a decreased CT in eyes with MH. Furthermore, Michalewska et al. [19] demonstrated irregularities in outer choroidoscleral boundaries in MH patients. We found significant choroidal thinning in eyes with MH compared with their fellow eyes in both groups, which was consistent with the findings of the reports noted above.

The choroid is the main blood supply of fovea; retinal capillary blood flow is significantly lower than in other retinal locations, especially the fovea [20]. Therefore, the choroid plays an important role in the metabolic activity of central fovea. Decreased choroidal blood flow and altered metabolic activity might alter the healing process and contribute to failed MH closure. In this study, however, when we analyzed MH characteristics and subfoveal CT together in the logistic regression analysis, we did not find any association between CT and anatomic success.

Table 5 Correlation of MH dimensions (minimum hole diameter and hole base diameter) and duration of symptoms with CT from various points

Choroidal thickness	Minimum hole diameter		Hole base diameter		Duration of symptoms	
	r	*p* value	*r*	*p* value	*R*	*p* value
Subfoveal	− **0.518**	< 0.001	− **0.505**	< 0.001	− **0.510**	< 0.001
Temporal 1500 µ	− 0.343	0.005	− 0.294	0.016	− 0.389	0.005
Nasal 1500 µ	− 0.309	0.011	− 0.276	0.024	− 0.366	0.008
Superior 1500 µ	− 0.265	0.030	− 0.279	0.022	− 0.275	0.051
Inferior 1500 µ	− 0.364	0.002	− 0.309	0.011	− 0.303	0.031

Subfoveal CT significanly correlated with MH dimensions and duration of symptoms are given in bold

MH macular hole, *CT* choroidal thickness

Conversely, we found that larger and chronic holes contributed to failed hole closure, which has been noted by previous studies [9, 10]. In other words, preoperative subfoveal choroidal thinning, which was encountered in open MHs, may have been the result of chronic and larger MHs. Indeed, there was a moderate correlation between subfoveal CT and MH dimensions and duration of symptoms. The patients who had larger MHs and longer durations of symptoms tended to have thinner preoperative subfoveal choroids (Fig. 1a, b) than patients who had small MHs and shorter duration of symptoms (Fig. 2a, b). A

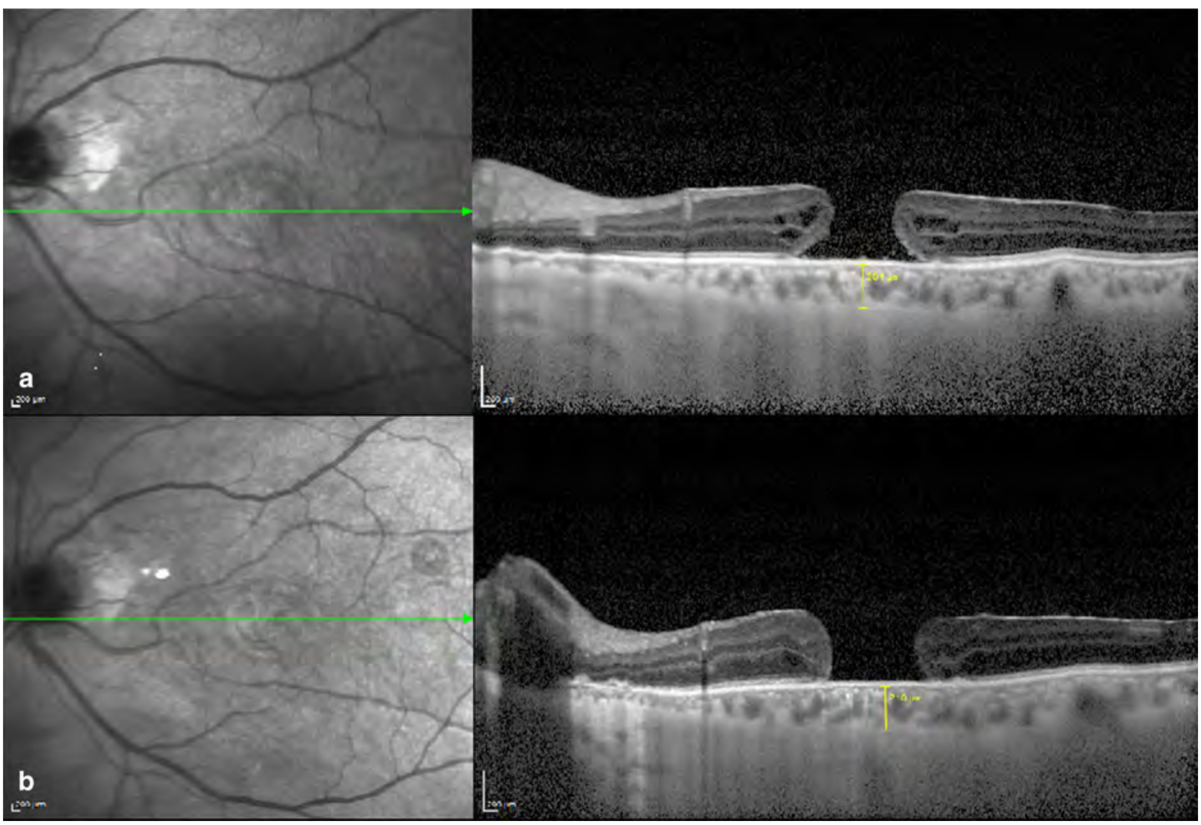

Fig. 1 Preoperative and postoperative EDI-OCT images of a 64-year-old patient who had complaints for 14 months. MH had flat margins. **a** Hole base diameter: 1400 µm, minimum hole diameter: 800 µm, axial length: 24 mm and subfoveal choroidal thickness: 204 µm. **b** Macular hole was not closed after surgery. Subfoveal choroidal thickness: 210 µ

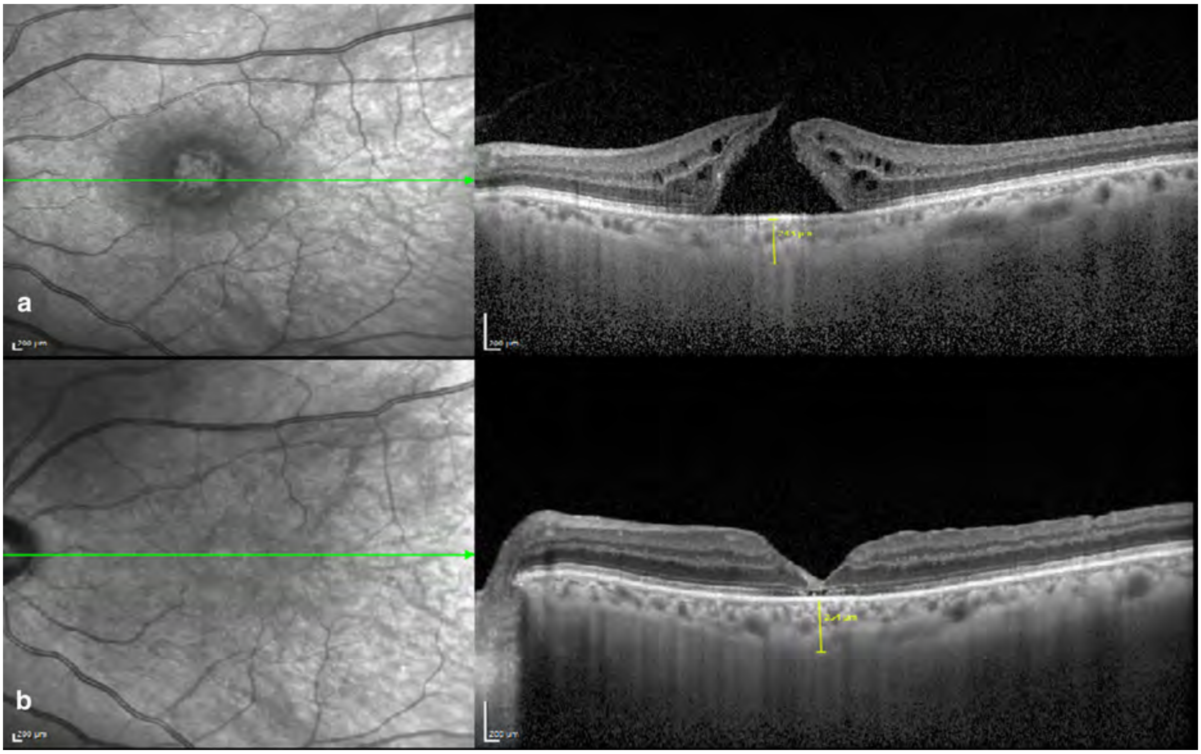

Fig. 2 Preoperative and postoperative EDI-OCT images of a 65-year-old patient who had complaints for 2 months. **a** Base diameter: 1542 µm, minimum diameter: 221 µm, axial length: 24 mm and subfoveal choroidal thickness: 243 µm. **b** Macular hole was closed after surgery. Subfoveal choroidal thickness: 254 µ

correlation of subfoveal choroidal thinning with chronic and larger MHs might be thought as data supporting the findings of Flügel et al. These authors suggested that overlying retinal tissue regulated choroidal blood flow [8]. In addition, Teng et al. [21] recently reported OCT angiographic findings in MHs. These authors found a negative correlation between choriocapillaris circulation and hole diameter. Furthermore, Allen et al. [22] demonstrated decreased choroidal perfusion following laser-induced MH formation.

In conclusion, preoperative subfoveal CTs appear to be thinner in open MHs. However, subfoveal choroidal thinning was not associated with anatomic success. Subfoveal choroidal thinning likely is the result of larger and chronic MHs.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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