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Original research

Choroidal thickness in idiopathic macular hole

Reza Karkhaneh, Masoud Nikbakht, Fatemeh Bazvand, Afshin Kalantary Oskouei, Hamed Ghasemi, Fariba Ghassemi*

Eye Research Center, Farabi Eye Hospital, Tehran University of Medical Sciences, Tehran, Iran

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Abstract

Purpose: To measure the submacular choroidal thickness in eyes with idiopathic macular hole (IMH) compared with unaffected fellow eyes and normal control eyes.
Methods: In this single institutional retrospective comparative case-control study, 34 consecutive patients with IMH were included and compared with 30 normal age- and sex-matched eyes that were planned to have cataract surgery. The included eyes were divided into 4 groups: 41 eyes with IMH (A), 23 unaffected fellow eyes (B), 30 normal eyes (C), and 12 vitrectomized IMH eyes (D).
Results: The choroidal thickness was significantly lower in all measured points in IMH eyes versus normal control eyes (subfoveal choroidal thickness [SFCT]: 215.76 ± 66.7 vs. 288.53 ± 72.0, $P < 0.001$) and at most locations in comparison between group B and C (SFCT: 231.79 ± 68.6 vs. 288.53 ± 72.0, $P = 0.018$). No significant difference was found in choroidal thickness between both eyes of patients with unilateral IMH ($P = 0.81$). The choroidal thickness was not altered after vitrectomy in the mean 6 months follow-up period. A negative correlation between the apical diameter and basal diameter of IMH and SFCT ($P = 0.05$) (P value of 0.034 and 0.05) and preoperative best-corrected visual acuity and apical and basal diameter of IMH ($P = 0.006$ and $P = 0.029$, respectively) was observed.
Conclusion: Choroidal thickness is reduced in both eyes of patients with IMH compared with normal age- and sex-matched control eyes.

Keywords: Choroidal thickness; Idiopathic macular hole; Macular hole

Introduction

Idiopathic macular hole (IMH), as the most common type of macular hole (MH), is characterized by full-thickness anatomic defect at the fovea, leading to loss of central vision.[1–3] Although it is generally accepted that IMH is caused by vitreofoveal traction,[4,5] other factors including degeneration of macular cyst, involutional macular thinning, pigment epithelium disease, hormonal influences, and systemic vascular disorders may be involved in its pathogenesis.[4,6,7] Recently, choroidal thinning in IMH was noted.[8–15] It is suggested that choroidal hypoperfusion plays a role in the macular thinning as a theoretical pathogenic factor causing IMHs.

The quantitative measurement of choroidal thickness is possible by using enhanced depth optical coherence tomography (EDI OCT). Recently, some studies found that patients with IMH have a reduced choroidal thickness, both in the affected and in the unaffected fellow eye, using EDI OCT.[8–10] It is hypothesized that the choroidal thinning may be an indicator of reduction in perfusion of foveal avascular zone and plays some roles in the creation or progression of IMH.[7,11]

In this study, we evaluated the choroidal thickness of patients with IMH and compared them with unaffected fellow eyes and healthy age- and gender-matched healthy control eyes.

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* Corresponding author. Eye Research Center, Farabi Eye Hospital, Qazvin Square, Tehran, 1336616351, Iran.
E-mail addresses: ghasemi_f@sina.tums.ac.ir, fariba.ghassemi@gmail.com (F. Ghassemi).
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Methods

This retrospective case-control comparative study was performed from 2012 to 2014. Institutional Review Board approval was obtained. Tenets of the Helsinki Declaration were followed. Staging of the MH was performed biomicroscopically with a slit lamp examination according to the Gass classification[9] and by OCT examination.[5] Consecutive patients examined at our retina clinic with a full-thickness (stage 2, 3, or 4) IMH in one eye and an unaffected fellow eye were recruited. For each patient with MH, each consecutive healthy subject with the same age and sex who fulfilled the inclusion and exclusion criteria was enrolled in the control group.

Patients with systemic disorders (diabetes mellitus and hypertension), high refractive errors (spherical equivalent beyond −3 and +3 diopters), axial lengths more than 24 and less than 22, amblyopia, any history of other ocular disease and operation, and patients with poor quality images were excluded. The images were obtained with the best visualization of the border between the choroid and the sclera known as the choroidal−scleral interface (CSI). If neither image had a clearly identifiable CSI, the patient was excluded. Thirty-four consecutive patients with unilateral or bilateral IMH and 30 age- and gender-matched healthy subjects (as the control group) were included in this study. Complete ophthalmic examination and axial length measurement were performed for all subjects by an optical instrument (IOL Master, Zeis IOL master 500, Germany). The visual acuity (best corrected visual acuity [BCVA]) was measured by Snellen chart and transformed to LogMAR.

Choroidal thickness was measured on EDI OCT images obtained by Heidelberg Spectralis OCT (Heidelberg Engineering, Heidelberg, Germany). The EDI image was averaged over 100 scans using the automatic averaging and eye tracking system. Five to seven sections, each comprising 100 averaged scans, were obtained in a 5 × 15-degree rectangle encompassing the macula, and the horizontal section directly crossing the center of the fovea was selected. All measurements were performed manually using Image J software version 1.45S (National Institutes of Health, Bethesda, Maryland, USA). B-scans were directly exported from the OCT machine and read into ImageJ software for processing. The choroidal thickness measurements were measured in micrometer and documented separately by two independent graders. The measurements were averaged for analysis. The distance between the outer portion of the hyper-reflective line of retinal pigment epithelium (RPE)-Bruch's membrane complex and the inner surface of choroid-scleral junction was measured. The choroidal thickness was measured at 7 points; at subfoveal choroidal thickness (SFCT), 0.5 mm, 1 mm and 2 mm nasally (N0.5, N1 and N2), and temporally (T0.5, T1 and T2) from foveal center (Fig. 1). Two diameters of the MH were measured as described by Ullrich et al,[3] with the apical diameter being the minimum distance at the neurosensory retinal defect, and the basal diameter being the distance at the base of the hole at the level of the RPE.

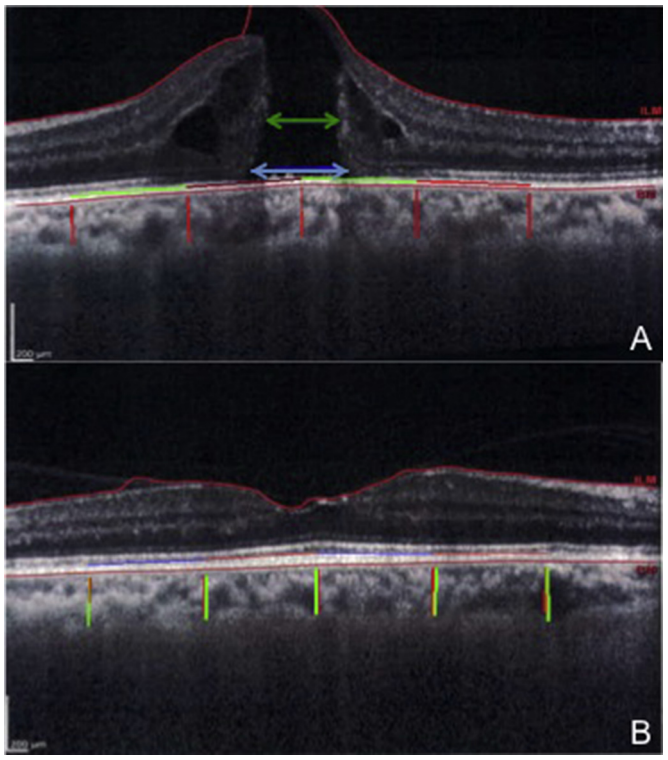

Fig. 1. A. Measurement of choroidal thickness at the fovea and 1 mm and 2 mm away from the fovea in the nasal and temporal directions. The green line refers to the apical diameter of the macular hole, and the blue line refers to the basal macular hole. B. The measurement of choroidal thicknesses at the fovea, 1 mm, and 2 mm from the foveal center in the contralateral eye of the same patient.

The height was measured as the highest perpendicular line from apical diameter line to RPE-Bruch complex, respectively. Four groups were defined in this study. The affected eyes were with IMH (group A), the normal fellow eyes of patients (group B), the normal eyes of healthy subjects as control samples (group C), and the same eyes after surgery (group D).

Statistical analysis

Statistical analysis was performed using a SPSS software, version 16.0 (SPSS, Inc, Chicago, IL). The data was analyzed descriptively (Mean ± SD). The assessment distribution was performed by Shapiro−Wilk test. Because of the small sample size, the Kruskal−Wallis nonparametric test was used for comparison between all four groups. The independent sample t-test was used for the comparison between choroidal thicknesses in the groups. Paired t-test and Chi-square test were used for other variables and comparison. With this number of variables, the P value was adjusted using the Bonferroni correction for finding the true significant differences.[15] The correlations between choroidal thickness and age, gender, axial length, diameters and height of the hole and BCVA, and diameter and height of the hole were assessed by Pearson correlation coefficient and approved by linear regression. P value less than 0.05 was considered significant.

Results

Forty and one eyes of Thirty-four patients (male/female: 15/19) with unilateral or bilateral IMH were included in this study. The mean age was 67.4 years (range: 47–78) for males and 62.3 years (range: 54–78) for females. Twenty-three normal fellow eyes of patients were recruited in group B. Nine patients had bilateral IMH. Thirty healthy subjects (male/female: 15/15) with the mean age of 65.9 years (range: 50–79) in males and 66 years (range: 54–80) in females were included as control group (group C). The demographic data of all groups is summarized in Table 1. No statistically significant differences were observed in age, gender, axial length, and refractive errors between the groups. Two graders measured the choroidal thickness. Good agreement between the graders for thickness measurements was observed (Kappa = 0.86).

Group A included 4 eyes in stage 1, 3 eyes in stage 2, 7 eyes in stage 3, and 27 eyes in stage 4. Choroidal thickness in stage 4 was insignificantly lower than other stages (P = 0.10). A significant negative correlation between SFCT and the apical diameter (P = 0.05, r = −0.46) was observed. A significant correlation was found between BCVA and hole diameter (apical and basal with P = 0.02, r = 0.38 and P = 0.04, r = 0.35, respectively). BCVA had no significant correlation with height of hole (P = 0.70, r = −0.06) and choroidal thickness (P = 0.05, r = 0.158).

A Kruskal–Wallis test showed a statistical difference between groups A and B (P < 0.001). The SFCT was significantly thinner than that in healthy controls (P < 0.001) (Table 2).

Moreover, the choroidal thickness values were significantly lower in group A than in group B in other locations, including 1 and 2 mm nasally and temporally to the fovea (marked as N1 mm, N2 mm, T1 mm, T2 mm) (Table 2). The control eyes had more thickness in all measured points compared with the IMH-containing eyes (Table 2). When comparing the unaffected eyes with the control eyes, the differences were significant except in the nasal and temporal 2 mm points. At these two points, the thicknesses were lower than in group C, but without statistical significance (Table 2). After excluding the patients with bilateral involvement in group A (group A1), the choroidal thickness was compared between the affected eye of patients with unilateral IMH and their normal fellow eyes. No significant difference was found in choroidal thickness between both eyes of patients with unilateral IMH (Table 2). Twelve patients with IMH were operated (group D). The choroidal thickness was not altered after vitrectomy during the mean follow-up period of 6 months (Table 3). Representative images of MH and choroidal thickness in a 61-year-old woman with unilateral IMH and the control contralateral eyes are shown in Fig. 1.

A negative significant correlation between choroidal thickness and age was found in group A, B, and C with exception of the location T2 in group C (Table 4). By linear regression analysis, no significant correlation between central choroidal thickness and axial length (P = 0.08, r = −0.23) and gender (P = 0.35, r = 0.23) was found in this study.

Table 1
Baseline characteristics of idiopathic macular hole (IMH) and control groups.

	Group A (no of eyes = 41)	Group C (no of eyes = 30)	P Value
Age (years)	65.4 ± 6.38	66.5 ± 7.80	0.86
Gender (male/female)	18/23	15/15	0.94
Refractive error (SE)	−0.49 ± 1.94	−0.39 ± 1.74	0.65
Axial length (mm)	23.18 ± 0.88	23.3 ± 0.87	0.83

NA: not assessed, No: number, SE: spherical equivalent. The affected eyes with IMH (group A) and the normal control eyes (group C).

Discussion

Choroidal thickness is reduced in both eyes of patients with IMH with no significant difference after vitrectomy. The choroidal thickness was significantly lower in all measured points in IMH versus normal control eyes. Choroidal thickness in stage 4 was insignificantly lower than other stages. A significant negative correlation between SFCT and hole diameter was detected.

With the widespread application of EDI OCT, choroid could be evaluated qualitatively and quantitatively. Choroid provides oxygen and other nutrients to the highly metabolic outer retina as well as to the RPE.[16] The choroid is thinner in age-related macular degeneration,[17] pathologic myopia,[18] retinitis pigmentosa,[19] age-related choroidal atrophy,[17] and retinopathy of prematurity.[20]

Our results support the results of other studies indicating that EDI OCT of patients with IMH have a reduced choroidal thickness, both in the affected and in the unaffected fellow eyes, compared with age- and gender-matched healthy controls (Table 5).[8–10]

Reibaldi and associates,[8] found no correlation between choroidal thickness and age in the eyes with a MH and fellow eyes, in contrast to the control eyes. They suggested anatomic or functional alterations, or both for this finding. Zeng and coworkers documented a moderate correlation with age in both groups of affected eyes and contralateral eyes in contrast to a highly significant correlation of these parameters in the normal group. In our study, there was a significant negative correlation between age and choroidal thickness in all groups A, B, and C, but the T2 location in group C.

Reibaldi and associates showed that choroidal thickness is significantly correlated with axial length, suggesting that this is a generalized feature not specifically related to MH formation. In contrast, in our study, gender and axial length had no significant correlation with choroidal thickness. This could be because of ethnic differences.

Xu et al recently evaluated the choroidal thickness in the patients with full thickness macular hole (FTMH) and contralateral eyes with vitreomacular adhesion (VMA). They compared the choroidal thickness of different locations of the patients with normal age- and sex-matched controls. They concluded that FTMH eyes had significantly thinner choroids than healthy eyes except at 2 mm temporal to the fovea. A significant thinning of the choroid in eyes with contralateral

Table 2
Mean choroidal thickness at five locations in the idiopathic macular hole (IMH), bilateral IMH excluded, normal fellow eyes, and the normal control eyes.

	Mean choroidal thickness ± SD (μm)				P Value (mean deviation, Kruskal–Wallis)			
	Group A (no of eyes = 41)	Group A1 (no of eyes = 23)	Group B (no of eyes = 23)	Group C (no of eyes = 30)	A-C	A-B	B-C	A1-B
SFCT	215.76 ± 66.7	221.64 ± 79.9	231.79 ± 68.6	288.53 ± 72.0	0.000*	0.000* (−72.76)	0.018* (−56.7)	0.81 (−10.14)
N0.5	201.34 ± 59.3	203.01 ± 68.2	212.6 ± 66.2	272.05 ± 74.6	0.000*	0.000* (−70.71)	0.008* (−59.45)	0.75 (−9.59)
N1	185.63 ± 55.3	184.94 ± 64.0	201.1 ± 63.0	250.97 ± 67.6	0.000*	0.000* (−65.33)	0.023* (−49.86)	0.6 (−16.15)
N2	146.98 ± 50.5	145.78 ± 60.4	159.17 ± 59.3	194.02 ± 59.9	0.008*	0.004* (−47.03)	0.151 (−34.84)	0.52 (−13.39)
T0.5	215.89 ± 61.9	218.36 ± 73.1	231.16 ± 61.0	285.03 ± 68.9	0.000*	0.000* (−69.14)	0.015* (−53.87)	0.92 (−12.8)
T1	211.41 ± 57.1	214.57 ± 67.9	229.65 ± 57.8	275.36 ± 60.8	0.000*	0.000* (−63.95)	0.033* (−47.71)	0.71 (−15.07)
T2	206.79 ± 50.1	215.86 ± 59.34	213.68 ± 53.7	251.26 ± 51.3	0.003*	0.003* (−44.46)	0.055 (−37.57)	0.85 (2.17)

IMH: idiopathic macular hole, SD: standard deviation, No: number, *: significant, SFCT: sub foveal choroidal thickness, N: nasal, T: temporal, 0.5: 0.5 mm from the fovea, 1: 1 mm from the fovea, 2: 2 mm from the fovea. The affected eyes with IMH (group A), the normal fellow eyes of patients (group B), and the normal eyes of healthy subjects as control samples (group C).

Table 3
Mean choroidal thickness and best corrected visual acuity at five locations in the idiopathic macular hole (IMH), pre- and post-vitrectomy.

	Mean choroidal thickness ± SD (μm)		P Value
	Group A (pre operation) No of eyes = 12	Group D (post operation) No of eyes = 12	
SFCT	225.89 ± 49.4	224.3 ± 49.9	0.95
N0.5	217.03 ± 50.7	216.62 ± 51.3	0.91
N1	198.08 ± 56.5	198.52 ± 55.9	0.92
N2	155.96 ± 48.7	152.69 ± 50.9	0.91
T0.5	228.98 ± 50.1	227.09 ± 48.9	0.92
T1	228.08 ± 56.4	227.94 ± 54.8	0.82
T2	213.94 ± 51.5	214.55 ± 48.2	0.77
BCVA	0.95 ± 0.38	0.55 ± 0.18	0.123

SD: standard deviation, No: number, BCVA: best corrected visual acuity, SFCT: sub foveal choroidal thickness, N: nasal, T: temporal, 0.5: 0.5 mm from the fovea, 1: 1 mm from the fovea, 2: 2 mm from the fovea. The affected eyes with IMH (group A) and the eyes after surgery (group D).

Table 4
Correlation between mean choroidal thickness and age at five locations in the idiopathic macular hole (IMH), normal fellow eyes, and control eyes.

	Group A (no of eyes = 41)	Group B (no of eyes = 23)	Group C (no of eyes = 30)
SFCT	P = 0.001	P = 0.006	P = 0.005
	r = −0.48	r = −0.55	r = −0.49
N0.5 mm	P = 0.001	P = 0.007	P = 0.003
	r = −0.48	r = −0.548	r = −0.51
N1 mm	P = 0.006	P = 0.008	P = 0.004
	r = −0.42	r = −0.542	r = −0.50
N2 mm	P = 0.001	P = 0.012	P = 0.001
	r = −0.48	r = −0.51	r = −0.58
T0.5 mm	P = 0.000	P = 0.014	P = 0.013
	r = −0.53	r = −0.50	r = −0.44
T1 mm	P = 0.001	P = 0.004	P = 0.006
	r = −0.50	r = −0.57	r = −0.48
T2 mm	P = 0.009	P = 0.003	P = 0.124
	r = −0.40	r = −0.58	r = −0.27

No: number, SFCT: sub foveal choroidal thickness, N: nasal, T: temporal, 0.5: 0.5 mm from the fovea, 1: 1 mm from the fovea, 2: 2 mm from the fovea. The affected eyes with IMH (group A), the normal fellow eyes of patients (group B), and the normal eyes of healthy subjects as control samples (group C).

VMA compared with healthy controls was demonstrated nasally from the fovea.[10]

Vitreoretinal anterior-posterior traction is generally viewed as one of the most important initiating factors in the development of MH.[5,13–16] MH formation without a vitreoretinal traction, even with a pre-existing complete posterior vitreous detachment or deep vitrectomy history, have been reported.[21–25] Trophic alteration in the retina and vascular alterations have been hypothesized in eyes with MH.[3,4,7]

Recently, Heidelberg retinal flowmetry showed that the mean blood flow and velocity were reduced in eyes with stage 4 and stage 1a MH compared with normal eyes.[26] They have proposed that choroidal hypoperfusion may be a factor for FTMH formation because of a decrease in nutrient transport and an increase in susceptibility to damaging factors.[26] The choroid contributes the blood supply to the outer retina, contributing to 100% blood and oxygen supply in the foveal avascular zone, where IMH occurs.[27]

The thinning of the choroids in all horizontally evaluated locations in our study, as in other studies, is more probably the cause of MH rather than a result of it. A six-fold higher risk of IMH formation in fellow eyes of patients in previous studies,[28] together with the observed choroidal thinning in unaffected eyes, propose some causative role of choroidal thinning in IMH formation. However, MH will develop in only 15% of fellow eyes, so there must be other more important factors as tractional forces or inner retinal layers ischemia.[9,26]

Several mechanisms intervene in choroidal blood flow regulation: myogenic autoregulation and receptor mediated flow. These mechanisms cooperate to maintain the choroidal volume and flow constant, despite alteration of ocular and systemic blood pressure.[29–32]

In 12 of our patients with IMH, after vitrectomy, the choroidal thickness was not changed during 6 months of follow-up. Similar result was reported by Fujiwara et al[11] with 40 patients and 3 months follow-up and Schaal et al[12] with 12 patients and a follow-up time of 6 months. More studies with longer follow-up periods will reveal choroidal thickness changes during the time.

Table 5
The results of several studies about choroidal thickness and macular hole.

Study	Sample size (patients)	Study year	Age(y)	SFCT in affected eye (μm) (1)	SFCT in fellow eye (μm) (2)	SFCT in normal eye (μm) (3)	Post operative (μm) (4)	P Value 1 vs. 2/1 vs. 3/1 vs. 4
Reibaldi et al[8]	22	2011	68	183	196	245	–	NS/<0.01/NA
Zeng et al[9]	50	2012	63	206	228	248.88	–	0.177/0.002/NA
Fujiwara et al[11]	40	2012	68.9	182	–	–	187 at 3 m	NA/NA/NS
Schaal et al[12]	12	2012	–	274	268	–	276 at 6 m	NA/NA/NS
Xu et al[10]	19	2015	65	215	197	262	–	0.0013/NA
Present study	34	2015	66	215	231	288	224 at 4.5 m	0.000/0.000/0.95

Y: year, SFCT: sub foveal choroidal thickness, vs.: versus, NS: not significant, NA: not available, m: month. μm: micrometer.

Our findings showed that the apical and basal MH diameters have a significant negative correlation with the SFCT in contrary to the results of other studies.[7] A similar correlation was found between preoperative BCVA and hole diameter. We did not notice any considerable relation between height of hole with choroidal thickness and preoperative BCVA.

A small sample size in each group, manual measurements, and a short follow-up period are the main limitations of our study. The vitrectomy was performed for some patients in this study, which could represent a possible selection bias.

In conclusion, choroidal thickness is reduced in both eyes of patients with IMH compared with control eyes, with no significant change after vitrectomy. It could be presumed that choroidal thickness is correlated with the MH and its stages. Further studies are needed to evaluate the possible role of choroidal thickness in MH formation.

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