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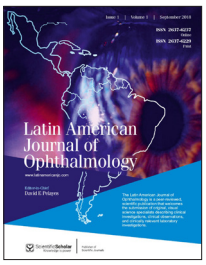

Retina *Case Series*

Association of the choroidal vascularity index with myopic traction maculopathy: A preliminary case-series report

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ABSTRACT

The choroidal vascularity index (CVI) is derived from the novel technique of assessing the choroidal vasculature by quantifying vascular flow using optical coherence tomography (OCT) images. Several retinal and choroidal diseases have been characterized using this index. However, no study has established the association of CVI with myopic traction maculopathy (MTM). This study aimed to investigate the association of CVI with different stages of surgically resolved MTM. We performed a consecutive, interventional, one-surgeon, and case-series study of 6 eyes of six patients enrolled between April 2017 and June 2022. One normal emmetropic eye (emmetropic control), one healthy myopic vision (healthy myopic control), and four surgically resolved myopic eyes at different stages of MTM (surgery group) were evaluated using OCT. The OCT images were binarized, and the total choroidal area (TCA, mm^2), vascular luminal area (LA, mm^2), and choroidal stromal area (SCA, mm^2) were quantified using ImageJ software. The CVI (%) was calculated as the ratio of LA to TCA. The primary outcome measure was the association of the CVI with the best-corrected visual acuity in either of the study eyes. The baseline patient characteristics were similar ($P > 0.05$), except for visual acuity, which was better in the control eyes ($P < 0.05$). The CVI was 68.2% in the emmetropic control eye and 61.5% in the healthy myopic vision, whereas the mean CVI in the surgical group was 47.8% (40.9–53.3, min to max) ($P = 0.07$).

Keywords: Choroidal vascularity index, Luminal area, Myopic traction maculopathy, Myopic foveoschisis, Foveoretinal detachment, Highly myopic eyes, Macular hole, Stromal choroidal area, Total choroidal area

INTRODUCTION

The choroid is a vascular structure that supplies most oxygen and nutrients to the retina and retinal pigment epithelium (RPE). Due to its role, choroidal thickness has been used as a robust tool in clinical research, as it affects several ophthalmic diseases.[1] However, choroidal thickness does not differentiate the vascular flow between the two stromal and luminal vascular components, and the measurements are also not reproducible. By determining the area of dark and light pixels corresponding to lumina (luminal area; LA) and stromal areas (stromal choroidal area; SCA) using noninvasive images, major components of the choroid can be represented by the vascular lumen of the vessels.[2] This parameter has been described in recent years and is calculated from optical coherence tomography (OCT) images through image binarization and quantification; it

is called the choroidal vascularity index (CVI). It is a novel tool to assess choroidal structure using non-invasive imaging procedures and techniques.[3-5] The CVI is calculated as the ratio of LA to total choroidal area (TCA), presented as a percentage.[6] Since the CVI reflects vascular changes in the choroid, it provides a unique opportunity to obtain perfusion information about the choroid.

Multiple studies have linked the association of the CVI with disease pathogenesis and progression. These include genetic, retinal, and macular diseases.[5,7,8] These studies suggest that the CVI can potentially be developed as a unique marker for retinal diseases. Since retinal diseases involve multiple factors, such as inflammation, edema, and leakage, the CVI has been suggested to be a potential marker because it represents the potential alterations that affect the integrity of the vascular network within the heavily blood-supplied retinal structure, that is, the choroid.[7,9] Therefore, it is believed that quantification of vascular factors can be a true representation of the ongoing disease pathogenesis.

Myopic traction maculopathy (MTM), a sight-threatening condition in individuals with high myopia, has received considerable attention for timely diagnosis and management, as it leads to multiple retinal pathologies if untreated on time.[10] Highly myopic eyes with macular foveoschisis and myopic foveoretinal detachment (FRD) naturally progress to the formation of macular holes (MHs).[11,12] Highly myopic eyes may develop macular foveoschisis in almost 34% of patients.[13-15] It is believed that macular foveoschisis and FRD are the precursors of MTM. Identifying these conditions early in pathogenesis would potentially help prevent vision loss. Morphological changes in high myopia are usually assessed using Doppler ultrasound and fundus fluorescein angiography (FFA). However, these methods have limitations, as Doppler ultrasound provides low-resolution images, and FFA is an invasive procedure. Monitoring MTM and treatment outcomes longitudinally through non-invasive reproducible methods would be a significant achievement for managing this disease.[16] Previously, vascular density in the macular region has been studied as a clinical measure in high myopia patients; however, the findings are variable.[16] CVI may be a sensitive tool because it accounts for microcirculatory changes in the retina,[17-19] and there have been reports of a functional correlation of visual acuity with vessel density in the macula and choroid.[20] Therefore, it is hypothesized that the CVI will predict the development of MTM in high myopia cases. For this study, the most recent MTM classification was adopted.[15,21] According to this classification, stage 1 disease is myopic foveoschisis (MF), stage 2 disease is foveoretinal detachment (FRD), stage 3 disease is myopic MH, and stage 4 disease is MH retinal detachment (MHRD).

Previously, CVI has been observed to be negatively affected by age.[22] Therefore, there have been several attempts to determine age-related normative data for CVI. It has also been reported that the CVI is not affected by confounding factors such as blood pressure, axial length, and intraocular pressure.[23] Therefore, it has been argued that the CVI may be a sensitive marker of disease progression. CVI distribution has also been reported to be highly consistent in the subfoveal, central submacular, and total submacular choroid. Recently, Tang *et al*.[24] assessed the choroidal thickness and vascularity index in high myopia cases after macular buckling surgeries. They found that the CVI increased at 1 and 3 months postoperatively and that the choroid thickened in the early post-operative period. Although many studies on high myopia have evaluated the CVI in their patient cohorts, there has been a substantial lack of comparative data between disease and age-matched control groups. Therefore, we aimed to evaluate the association of the CVI with different stages of MTM for its potential use as a marker of disease progression and pathogenesis. To the best of our knowledge, the present study is the first to compare CVI values across different stages of MTM with the CVI of normal control subjects. Therefore, these preliminary findings are expected to provide significant clinical insight into managing MTM.

MATERIAL AND METHODS

Study design

In this retrospective, interventional, one-surgeon, case–series report, one normal emmetropic eye, one healthy myopic eye [Figure 1], and four operated and structurally fully resolved myopic eyes at different stages of MTM (surgery group) were evaluated using OCT. The surgery group included consecutively enrolled patients from April 2017 to June 2022 who underwent a vitrectomy procedure using different internal limiting membrane (ILM) removal surgical techniques for symptomatic MTM. Only selected eyes at each stage of the condition where surgery was successful were included in the study. The disease was staged as shown in [Table 1]. The long-term post-operative enhanced high-definition (HD) 9-mm horizontal OCT images were binarized, and the TCA and LA were quantified using ImageJ software. The CVI (%) was calculated as the ratio of LA to TCA.

This study was conducted in the Retina Department at Oftalmologia Integral ABC, Mexico City, Mexico. The institutional review board approved the study, and written informed consent was obtained from all patients per institutional guidelines; no reference number is provided for retrospective studies by this institution. In this report, the stage of the disease, the study details and the inclusion criteria are listed in [Table 1].

The participants were matched for age, sex, study period, and follow-up duration. Patients were evaluated and

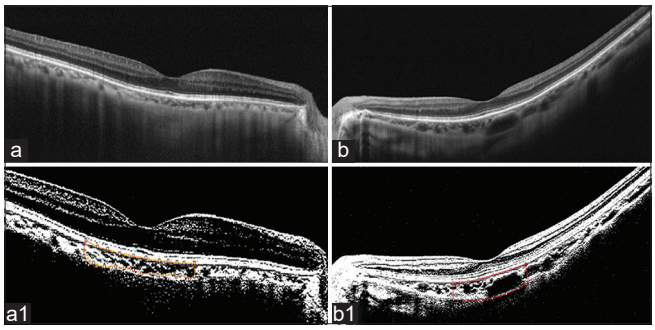

Figure 1: *Normal control groups.* (a) Enhanced high-definition (HD) 9-mm horizontal B scan designed to depict more detail of the intraretinal structure and choroidal layers in a normal eye. (a1) Corresponding horizontal B scan with binarized processing of the subfoveal choroidal stroma and luminal vascular visualization of the subfoveal choroidal vessels to obtain the choroidal vascularity index (CVI) of a normal emmetropic eye. The selected subfoveal area is clearly delineated with the yellow dotted line. (b) HD 9-mm horizontal B scan of a healthy highly myopic eye with enhanced choroidal vessel visualization to quantify the CVI. (b1) Corresponding binarized image with a red dotted line clearly delineating the selected subfoveal choroidal vascular area.

Table 1: Summary of study groups and inclusion criteria.

Study group	Inclusion criteria
Control emmetropic (*n*=1)	Spherical equivalent refractive error of +0.25 diopters and axial length of 20.72 mm
Control high myopia (*n*=1)	Spherical equivalent refractive error of −13.0 diopters and axial length of 29.5 mm
Surgical treatment group (*n*=4)	One eye exhibiting myopic foveoschisis One eye with evidence of foveoretinal detachment One eye with evidence of a macular hole One eye with macular hole retinal detachment

followed longitudinally. None of the selected eyes included in the study received intravitreal injections or laser photocoagulation during the study period. In addition to the selection criteria described in [Table 1], none of the eyes had evidence of patchy foveal-affected chorioretinal atrophy, diffuse macular chorioretinal atrophy, or quiescent or active myopic choroidal neovascularization (CNV) according to the ATN classification.[25] The diagnosis of different stages of MTM was confirmed using magnified spectral-domain OCT (SD-OCT) findings. All four eyes were followed up for more than 6 months with different time frames of the post-operative follow-up period. The four examined eyes included in this report underwent a post-operative long-term perfusion evaluation with OCTA and binarization of the enhanced HD 9-mm horizontal B scan images to calculate the CVI.

Quantification of CVI

The long-term post-operative CVI was measured through swept-source OCT of the macula. The enhanced HD 9 mm OCT-B images were uploaded to the ImageJ program (version 1.53; NIH, Rasband, and contributors, USA, public domain) and changed to an 8-bit format. After that, the brightness was lowered to the minimum, and the images were binarized. When the binarized images were obtained, the area of the subfoveal choroid was chosen manually between 750 microns nasal and 750 μ temporal in a horizontal plane from the center of the fovea and in a vertical fashion from the RPE-Bruch membrane complex to the scleral border. After that, the program analyzed the stromal vascular tissue area by counting the white pixels and dividing the count by the TCA, giving the result in a percentage value; the resulting percentage was the CVI, which is defined as the vascular LA divided by the TCA.

Surgical procedures

The surgical procedures were performed by a single highly experienced macular surgeon (MAQR). The surgical technique completed in this case-series report has been described previously.[26] Briefly, classical ILM peeling techniques were used in the MF case, the fovea-sparing ILM peeling technique was used in the FRD case, and the inverted-flap ILM peeling technique was used in the MH and MHRD cases. All of these techniques were performed using a 25-gauge vitrectomy cut and suction instrument (Alcon Constellation Vision System), 25-gauge diamond-dusted membrane scraper, and 25-gauge 0.44 forceps (Grieshaber Revolution DSP ILM forceps, Alcon Labs, Fort Worth, TX). ILM flap manipulation was facilitated by the use of a 25-gauge *Finesse* ILM flex loop microinstrument (Grieshaber, Alcon Labs).

RESULTS

The patient demographic data and preoperative clinical characteristics are summarized in [Table 2]. The pre-operative and post-operative functional changes and the type of surgical macular approach according to the MTM stage are described in [Table 3]. The postoperative quantifications of the CVI, LA, and TCA are summarized in [Table 4].

The quantification of the TCA, LA, and CVI of the control eyes compared with the post-operative TCA, LA, and CVI in the different post-operative MTM stages is shown in [Figure 2a-c], respectively.

The correlated statistical analysis of the post-operative TCA and the best-corrected visual acuity (BCVA) are plotted on the X- and Y-axes, respectively. Each dot represents data from one case. The blue line depicts the linear regression of the data

Table 2: Patient demographic data and pre-operative clinical characteristics.

Case	Age	Gender	Eye	Condition	Axial length (mm)	Follow up period (months)	Preoperative BCVA (logMAR)
Control	59	Female	Right	Emmetropic	21.3	NA	0
Control	65	Female	Left	Healthy myopic	28.18	NA	0
1	56	Male	Right	MTM stage 1 (MF)	27.32	31	0.78
2	48	Male	Right	MTM stage 2 (FRD)	28.28	56	1.00
3	58	Female	Right	MTM stage 3 (MH)	29.82	29	1.30
4	62	Female	Left	MTM stage 4 (MHRD)	31.26	18	1.90

BCVA: Best-corrected visual acuity, logMAR: Logarithm of the minimum angle of resolution, NA: Not applicable, MTM: Myopic traction maculopathy, MHRD: Macular hole retinal detachment

Table 3: Surgical data and visual outcomes.

Case	Pre-operative weeks with MTM	Surgical technique	Tamponade	Post-operative BCVA (logMAR)	Change in BCVA (logMAR)
1	4	Classical ILM	Gas	0.48	−0.30
2	5	FSIP	Gas	0.54	−0.46
3	9	Inverted Flap	Gas	0.70	−0.60
4	1	Inverted Flap	Silicon	1.18	−0.72

BCVA: Best-corrected visual acuity, FSIP: Fovea-sparing internal limiting membrane, ILM: Internal limiting membrane, logMAR: Logarithm of the minimum angle of resolution, MTM: Myopic traction maculopathy

Table 4: Post-operative choroidal measurements.

Case	Condition	LA (mm^2)	TCA (mm^2)	CVI (%)
Control	Emmetropic	0.292	0.428	68.2
Control	Healthy myopic	0.192	0.312	61.5
1	MF	0.212	0.398	53.3
2	FRD	0.254	0.512	49.6
3	MH	0.165	0.348	47.4
4	MHRD	0.122	0.298	40.9

CVI: Choroidal vascularity index, FRD: Foveoretinal detachment, LA: Luminal area, MF: Myopic foveoschisis, MH: Macular hole, MHRD: Macular hole retinal detachment, TCA: Total choroidal area

[Figure 3a]. Likewise, the correlation analyses of the post-operative LA and the BCVA are plotted on the X- and Y-axes, respectively. Each dot represents data from one case. The blue line depicts the linear regression of the data [Figure 3b]. Finally, the correlated analysis of the post-operative CVI and the BCVA are plotted on the X- and Y-axes, respectively. Each dot represents data from one case. The blue line depicts the linear regression of the data [Figure 3c].

Statistical analysis

Descriptive statistical analysis between groups is only given due to the extremely small sample size. Correlation analysis with all six cases is not ideal but was performed since it could be useful to generate hypotheses, which are discussed below. In this case, we gathered choroidal measurements from all six eyes and performed correlation analysis with postoperative BCVA. Pearson's r correlation was calculated, along with the p value of the significance of the correlation [Table 5].

Here, all three correlations are negative, meaning that higher CVI/LA/TCA is correlated with lower logMAR and hence better vision. However, only CVI has a statistically significant *P*-value. LA and TCA results are not statistically significant; a larger sample may help with finding statistical significance. All of the analysis files and figures can be found at the following link:

https://www.dropbox.com/sh/diqj75r9ox4t43h/AAD64kddlk4gKdas0hL83ZYva?dl=0.

Surgical case 1 (MFs)

A 56-year-old symptomatic male complained of metamorphopsia and visual loss in his right eye over 7 months. The pre-operative visual acuity was 0.78 in logMAR units (20/120 Snellen equivalent), and the applanation ocular tension was 11 mmHg. This eye had an axial length of 27.32 mm with PS, and the preoperative OCT findings were consistent with macular thickening due to schisis of the internal and external retina layers [Figure 4a]. After a 31-month follow-up, the center of the macular region appeared thinner with a normal foveal profile, no evidence of a MH and final vision of 0.48 in logMAR units (20/60 Snellen equivalent). Furthermore, some recognizable SD-OCT biomarkers, such as a normal foveal contour and internal and external neuroretina lines, and total

Table 5: Correlation analysis of the choroidal measurements.

Statistical test	Source file	*t*-statistic	*P*-value	Correlation coefficient
Correlation, CVI versus BCVA	Correlation_test_CVI_BCVA.txt	−6.7782	0.0025	−0.959
Correlation, LA versus BCVA	Correlation_test_LA_BCVA.txt	−2.1191	0.1014	−0.727
Correlation, TCA versus BCVA	Correlation_test_TCA_BCVA.txt	−0.54004	0.6178	−0.261

CVI: Choroidal vascularity index, LA: Luminal area, TCA: Total choroidal area, BCVA: Best-corrected visual acuity

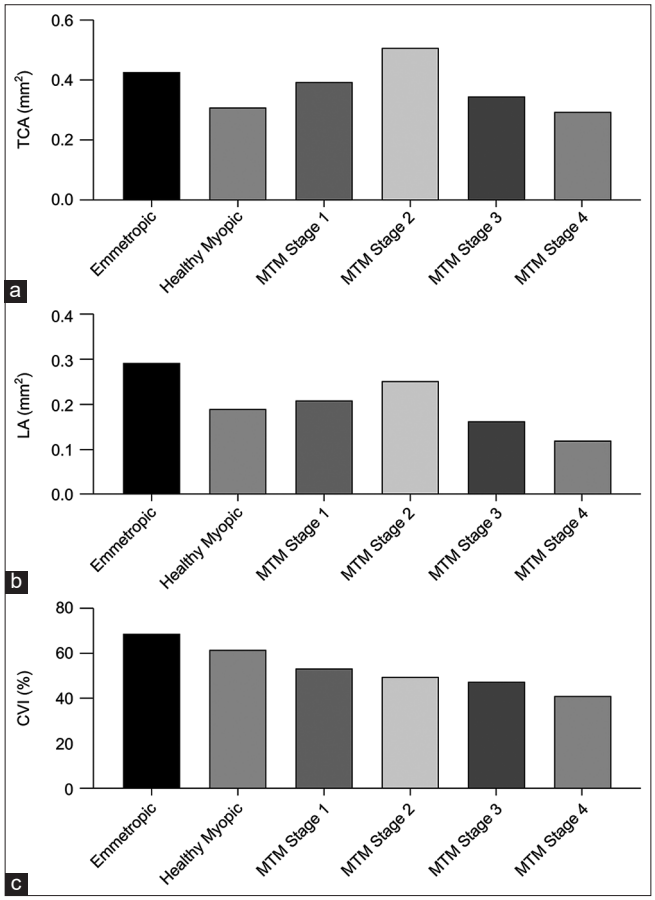

Figure 2: (a) TCA. (b) LA and (c) CVI among the six cases. TCA: Total choroidal area, LA: Luminal area, CVI: Choroidal vascularity index.

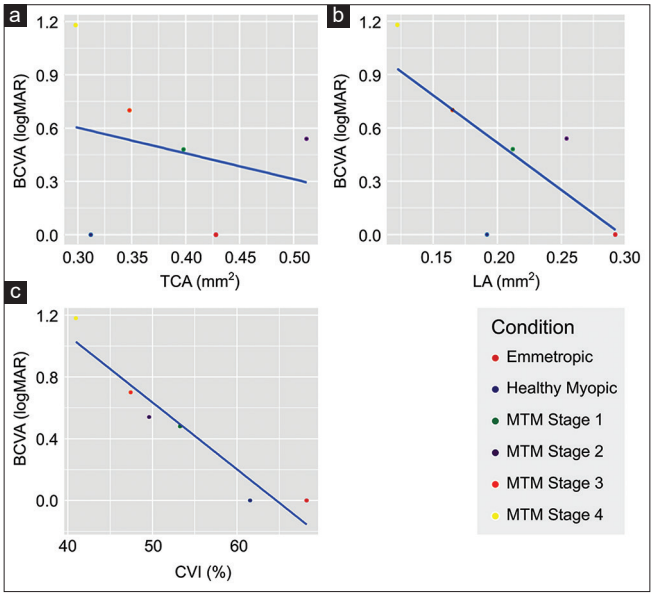

Figure 3: (a) Correlation between TCA and BCVA. (b) Correlation between LA and BCVA. (c) Correlation between CVI and BCVA. TCA: Total choroidal area, LA: Luminal area, CVI: Choroidal vascularity index, BCVA: Best-corrected visual acuity.

restoration of the central subfoveal ellipsoid zone (EZ), including at the IS/OS line and the external limiting membrane, were observed [Figure 4a1]. The long-term post-operative perfusion evaluation was abnormal, with a CVI index of 53.3%, lower than the one in the control healthy myopic eye [Figure 4a2].

Surgical case 2 (FRD)

A 48-year-old symptomatic male presented with metamorphopsia, a progressive drop in central vision, and high myopia. He had PS in both eyes; the right eye, which had an axial length of 28.28 mm, underwent macular surgery because of a 9-month history of symptomatic myopic FRD [Figure 4b]. The pre-operative BCVA was 1.00 in logMAR units (20/200 Snellen equivalent); After a 56-month longitudinal follow-up, the operated eye showed a postoperative logMAR vision of 0.54 units (20/70 Snellen equivalent), no evidence of progression to MH, a flat macula with no evidence of subretinal fluid in the SS-OCT, and some mild diffuse optic nerve fiber (DONFL) defects [Figure 4b1]. The post-operative long-term CVI calculated from the binarized image was 49.6% with a TCA of 0.512 mm² and an LA of 0.254 mm² [Figure 4b2].

Surgical case 3 (MH)

A 58-year-old female with 5 months of disabling metamorphopsia, high myopia, and a deep and irregular PS underwent macular surgery on the phakic right eye due to a full-thickness MH and tractional elongation of Henle's layer [Figure 4c]. The preoperative BCVA was 1.30 in logMAR units (20/400 Snellen equivalent), and the axial length was 29.82 mm. After a 29-month follow-up, the final postoperative vision was 0.70 in logMAR units (20/100 Snellen equivalent). and an abnormal macular profile, mild

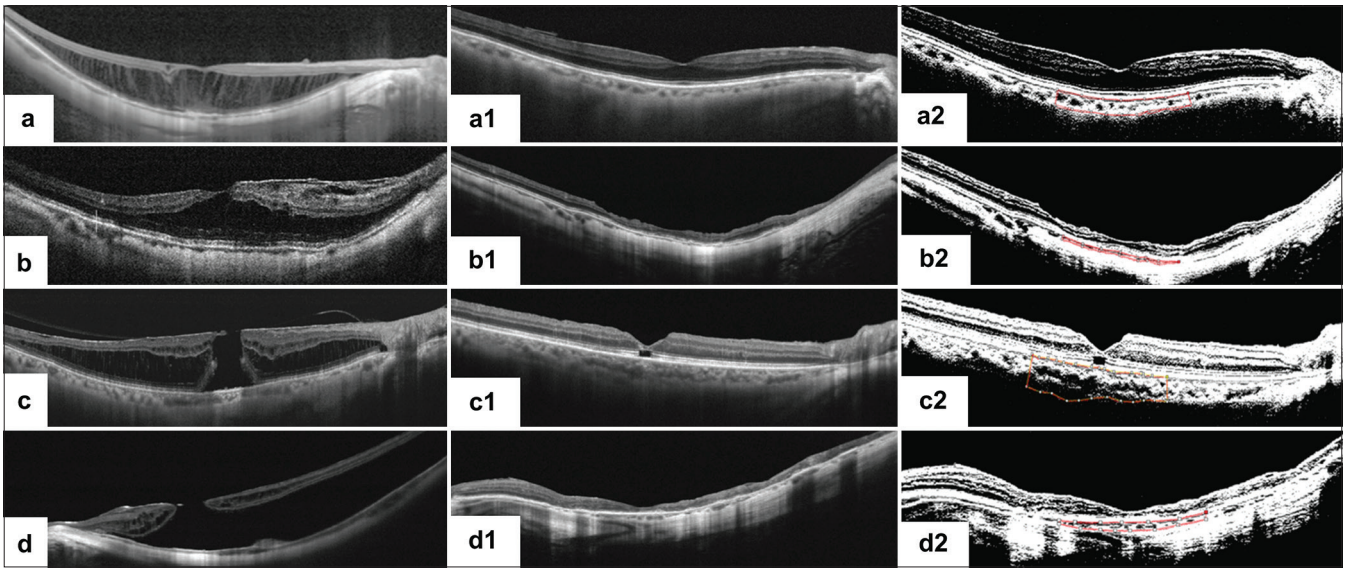

Figure 4: *Surgical cases.* (a) Pre-operative OCT findings were consistent with myopic foveoschisis due to macular thickening and schisis-like thickening of the internal and external retina layers. (a1) After a 31-month follow-up, the center of the macula region looked thinner with a normal foveal profile and without evidence of a macular hole. SD-OCT biomarkers, such as a normal foveal contour and internal and external neuroretina lines with total restoration of the central subfoveal EZ, were observed. (a2) Postoperative long-term binarized image with a CVI index of 53.3%. (b) Myopic FRD with subretinal fluid and a very thin foveal superficial layer. (b1) Long-term postoperative horizontal B scan with diffuse thinning of the retinal layers and evidence of FRD flattening. (b2) The CVI calculated from the binarized image was 49.6%. (c) Highly myopic eye with moderate posterior staphyloma. Evidence of a full-thickness myopic macular hole with tractional elongation of Henle's layer and thickening of the macula without evidence of macular detachment. (c1) The postoperative structural evaluation showed a flat macula with a recovered foveal profile, an ELM line lucency defect and a well-preserved RPE layer. (c2) The CVI was 47.4%. (d) Preoperative SS-OCT of an extensive retinal detachment-related myopic macular hole. (d1) This image depicts the long-term postoperative appearance with extrafoveal chorioretinal atrophic areas, an irregular foveal profile, thin foveal roof, nicely closed macular holes, macula reattachment without evidence of residual subretinal fluid, attenuated internal and external retina layers, subfoveal IS/OS (EZ), and an ELM line. (d2) The quantified choroidal perfusion indices were lower than the one obtained in the healthy myopic eye, with a very low CVI of 40.9%. The selected subfoveal area is clearly delineated by the red and yellow dotted lines in the binarized panels. OCT: Optical coherence tomography, CVI: Choroidal vascularity index, EZ: Ellipsoid zone, FRD: Foveoretinal detachment, ELM: External limiting membrane, SD-OCT: Spectral-domain optical coherence tomography.

DONFL defects, abnormal SD-OCT biomarkers such as internal and external retina OCT layers, a subfoveal IS/OS, an ELM line lucency defect, and a well-preserved RPE layer were observed [Figure 4c1]. The perfusion evaluation was abnormal in both retinal plexuses, with lower perfusion indices than normal (not shown). The CVI was 47.4% and was lower than the CVI of the healthy myopic eye [Figure 4c2].

Surgical case 4 (MHRD)

A 62-year-old woman with 2 months of slowly progressive decreased vision with metamorphopsia, high myopia, multiple areas of extrafoveal chorioretinal atrophy, and severe PS underwent on the phakic left eye for an MHRD of the posterior pole extending to three retinal quadrants. Preoperative SS-OCT confirmed an MHRD [Figure 4d]. The preoperative vision was 1.90 logMAR units (20/1600 Snellen equivalent), with a well-defined PS and an axial length of 31.26 mm. After an 18-month follow-up, the final postoperative BCVA was 1.18 in logMAR units (20/300 Snellen equivalent), and an SD-OCT pattern consistent with a fully attached retina, sealed and closed MH, extrafoveal areas of patchy chorioretinal atrophy, an abnormal foveal profile, a thin foveal center, attenuated internal and external retina SD-OCT layers, a subfoveal IS/OS (EZ), and an ELM line were observed [Figure 4d1]. A very abnormal perfusion evaluation on the SVP with better perfusion evaluation on the DVP (not shown). The quantified choroidal perfusion indices were lower than the ones obtained in the healthy myopic eye, with a very low CVI of 40.9% [Figure 4d2].

DISCUSSION

The present study investigated the CVI as a potential biomarker for MTM. Data were compared between two eyes in the control group (one healthy emmetropic eye and one healthy highly myopic eye) and an intervention group (patients with MTM related to high myopia). The results showed that the CVI was significantly lower in the disease group than in

the control healthy eyes. These findings imply that the CVI may indicate disease pathology in MTM. A lower CVI in diseased eyes suggests that choroidal vascular defects caused by pathologic myopia or surgery procedures can influence the manifestation, progression and functional outcomes in the different stages of surgically resolved MTM. This study was not designed to quantify the preoperative CVI in the different stages of this condition; consequently, it was not possible to comparatively evaluate the pre-operative CVI with the post-operative values to infer vascular damage hypothetically caused by transoperative alterations of the choroidal perfusion.

Pre-operative patient characteristics were similar and were directly comparable except for visual acuity, which was expected to be poor in the disease group. We found that the TCA and the CVI differed between the normal subjects and MTM patients. However, the CVI was similar among the surgical groups in the four patients. The results support the use of the CVI as a noninvasive biomarker; it distinguished patients in the MTM group from patients in the healthy control group. It has been reported that age and CVI are inversely related in healthy eyes.[22] The results also showed that the ILM surgical techniques were inversely correlated with the CVI, but we could not find a statistically significant relationship due to the low number of eyes. This would be a novel finding and signal that this procedure likely does not favor better long-term visual recovery in MTM patients. Regardless of this observation, a surgical intervention significantly improved visual acuity in all participants.

In the present study, we compared the CVI across different stages of MTM with that of the medical control eyes. The CVI for disease stages 1, 2, and 3 differed from that of the medical control group. Because of the small sample size in this preliminary case-series report, no normative data were obtained for each disease stage. Consequently, the data may not be directly comparable for making conclusions, but the results indicate that quantification of the CVI can predict disease severity across MTM stages. Agrawal *et al*.[4,5,7] reported the normative database for CVI from a population-based study on 345 healthy eyes through choroidal enhanced depth imaging OCT scans. They reported that the mean subfoveal CVI was 65.61 ± 2.33%. The CVI in the medical group in the present study was 65.35 ± 4.03%, which is comparable to published data.[4] The CVI in the surgical group was significantly less than that in the medical group and was markedly variable across patients, with a median value of 47.8 ± 5.20%. Yazdani *et al*.[2] evaluated the CVI in low myopic and emmetropic eyes. They reported that myopes showed a slightly higher CVI than emmetropes.[2] Although we presented data from high myopes and the findings are not comparable to those of Yazdani *et al*.,[2] the contrasting results indicate that further studies would be required to quantify the CVI in myopic subjects.

The CVI has been proposed as a novel OCT-based parameter to quantify structural changes in underwent scleral buckling procedures revealing low macular perfusion indices,[27] choriocapillaris flow reduction in placoid chorioretinitis[28] and type 1 age-related submacular neovascularization,[29] and eyes with multiple retinal dystrophies, such as retinitis pigmentosa (RP), Stargardt disease, cone-rod dystrophy, Best disease and Bietti crystalline dystrophy.[30] The literature suggests loss of the choriocapillaris with the overlying RPE in RP, as seen in *ex vivo* human eyes, suggesting the presence of choroidal vascular changes in inherited retinal diseases.[31] Wei *et al*.[30] reported that the CVI was decreased significantly in patients with retinal diseases, with a mean CVI of 52 ± 9%, whereas the CVI in normal eyes was 70 ± 3%. These findings are comparable to those from our study cohort. Earlier, Tan *et al*.[32] also reported that the mean CVI in eyes with RP was significantly lower than that in normal eyes. The authors considered that a lower CVI in choroidal vascular defects in RP could influence the manifestation and progression of the disease, which potentially makes this parameter a surrogate marker in monitoring and analyzing the progression of RP.[32] The literature suggests that retinal venular and arteriolar oxygen saturation is significantly higher in patients with RP, which also correlates with functional damage.[33] Iovino *et al*.[34] reported that the CVI is decreased significantly in patients with CME associated with RP, indicating a potential role of altered choroidal hemodynamics in the development of CME in RP. Through a retrospective comparison of the CVI and subfoveal choroidal thickness (SFCT) in patients with Stargardt disease and age- and sex-matched healthy controls, Ratra *et al*.[35] concluded that the CVI is a more robust tool than the SFCT for assessing choroidal changes in Stargardt disease and can be a potential surrogate marker for disease monitoring. They reported that the CVI was significantly decreased in eyes with the disease compared to those in the normal control group, and there was a negative association between visual acuity and CVI.[35] The increased choroidal vascularity observed in posterior uveitis is interpreted as an indirect indicator of intraocular inflammation, as reported by Agrawal *et al*.[7] and Kim *et al*.[9]

Decreased CVI has been reported in tubercular multifocal serpiginous choroiditis.[3] Agrawal *et al*.[4,5,7] also studied the application of the CVI in monitoring Vogt-Koyanagi-Harada disease. They observed that the CVI decreased over time, similar to the choroidal thickness. Choroidal thickness is useful for monitoring initial response to treatment but is not a robust tool to evaluate long-term outcome. Therefore, the CVI is proposed as a better outcome measure in chorioretinal diseases.[5] Koh *et al*.[36] assessed the CVI in patients with AMD and controls. They determined that the SFCT was similar across the study groups, but the CVI was significantly lower in patients with AMD.[36] Ng *et al*.[37] evaluated choroidal structural changes in eyes with myopic CNV treated with

anti-VEGF over 12 months. They reported thinning of the subfoveal choroid without alteration in the CVI in treated eyes. More recently, Hwang *et al*.[38] reported significantly decreased CVI in cases of branch retinal vein occlusion and macular edema. The authors suggested that the fellow eye CVI could be a useful supplementary prognostic biomarker in these diseases. Another possible mechanism for decreased CVI was considered to be the extracellular fluid shift from the retina to the choroid. Another cause of decreased CVI in BRVO is the pressure effect of choroidal congestion.[8] The CVI has also been reported to be significantly lower in eyes with central serous retinopathy with CNV.[39] It is suggested that choroidal vascular alterations may be associated with CNV in these conditions. The reason for the decreased CVI in the MTM cases could be vascular, trophic-tractional degeneration due to high myopia and histopathological changes from PS.

The major limitation of the present study is the small sample size, which prevented us from obtaining normative data for each stage of the disease to facilitate a comparison of outcomes with other diseases. In addition, the correlation of the CVI with retinal functional damage assessment techniques such as multifocal ERG, automated microperimetry and autofluorescence imaging may further increase the understanding of the disease process and the potential to develop noninvasive methods as disease biomarkers. However, those methods were not included in the present study, as we focused only on quantifying the CVI across normal subjects and different stages of the disease.

There has been significant development in imaging tools and assessment techniques for retinal diseases using objective and noninvasive techniques. The CVI is one of the innovative tools recently proposed as a novel marker for choroidal pathogenesis. The present study also showed that the CVI might indicate MTM development in highly myopic eyes. Despite the small sample size, the results are conclusive and strongly support the study's hypothesis. However, the CVI is not a unique marker of MTM, as it has been previously described for a wide range of retinal diseases. Notwithstanding this specificity limitation, we propose that comparison of the CVI between the two eyes and with normal subjects would be helpful in monitoring pathology in MTM. Further studies are warranted, especially to determine the range of the CVI values for each stage of the disease so that direct comparisons can be made for objective analysis of disease progression.

CONCLUSION

The CVI was strongly associated with MTM and correlated with disease severity in high myopia cases. Further prospective studies analyzed with uni- and multivariate regression formulas are required to determine statistically reliable quantitative data at each stage of the disease for better use of the CVI as a potential biomarker in disease pathogenesis.

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Author contributions

MAQR: Study conception, writing the manuscript, dataset interpretation, statistical analysis interpretation, final revision, conclusions. EAQG: Figures artwork, statistical dataset, tables, photographic material compilation, graphics. MAQG: Assistant surgeon. VLG: Statistical analysis, final revision. All authors approved the manuscript for submission.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Tan KA, Gupta P, Agarwal A, Chhablani J, Cheng CY, Keane PA, *et al*. State of science: Choroidal thickness and systemic health. Surv Ophthalmol 2016;61:566-81.
2. Yazdani N, Ehsaei A, Hoseini-Yazdi H, Shoeibi N, Alonso-Caneiro D, Collins MJ. Wide-field choroidal thickness and vascularity index in myopes and emmetropes. Ophthalmic Physiol Opt 2021;41:1308-19.
3. Agarwal A, Agrawal R, Khandelwal N, Invernizzi A, Aggarwal K, Sharma A, *et al.* Choroidal structural changes in tubercular multifocal serpiginoid choroiditis. Ocul Immunol Inflamm 2018;26:838-44.
4. Agrawal R, Gupta P, Tan KA, Cheung CM, Wong TY, Cheng CY. Choroidal vascularity index as a measure of vascular status of the choroid: Measurements in healthy eyes from a population-based study. Sci Rep 2016;6:21090.
5. Agrawal R, Li LK, Nakhate V, Khandelwal N, Mahendradas P. Choroidal vascularity index in Vogt-Koyanagi-Harada disease: An EDI-OCT derived tool for monitoring disease progression. Transl Vis Sci Technol 2016;5:7.
6. Iovino C, Pellegrini M, Bernabei F, Borrelli E, Sacconi R, Govetto A, *et al*. Choroidal vascularity index: An in-depth analysis of this novel optical coherence tomography parameter. J Clin Med 2020;9:595.
7. Agrawal R, Salman M, Tan KA, Karampelas M, Sim DA, Keane PA, *et al*. Choroidal vascularity index (CVI)-a novel optical coherence tomography parameter for monitoring patients with panuveitis? PLoS One 2016;11:e0146344.

8. Aribas YK, Hondur AM, Tezel TH. Choroidal vascularity index and choriocapillary changes in retinal vein occlusions. Graefes Arch Clin Exp Ophthalmol 2020;258:2389-97.
9. Kim M, Kim RY, Park YH. Choroidal vascularity index and choroidal thickness in human leukocyte antigen-B27-associated uveitis. Ocul Immunol Inflamm 2018;27:1280-7.
10. Ohno-Matsui K, Kawasaki R, Jonas JB, Cheung CM, Saw SM, Verhoeven VJ, *et al*. International photographic classification and grading system for myopic maculopathy. Am J Ophthalmol 2015;159:877-83.e7.
11. Shimada N, Tanaka Y, Tokoro T, Ohno-Matsui K. Natural course of myopic traction maculopathy and factors associated with progression or resolution. Am J Ophthalmol 2013;156:948-57.e1.
12. Shimada N, Ohno-Matsui K, Baba T, Futagami S, Tokoro T, Mochizuki M. Natural course of macular retinoschisis in highly myopic eyes without macular hole or retinal detachment. Am J Ophthalmol 2006;142:497-500.
13. Ikuno Y, Tano Y. Early macular holes with retinoschisis in highly myopic eyes. Am J Ophthalmol 2003;136:741-4.
14. Panozzo G, Mercanti A. Optical coherence tomography findings in myopic traction maculopathy. Arch Ophthalmol 2004;122:1455-60.
15. Margolis R, Spaide RF. A pilot study of enhanced depth imaging optical coherence tomography of the choroid in normal eyes. Am J Ophthalmol 2009;147:811-5.
16. Fan H, Chen HY, Ma HJ, Chang Z, Yin HQ, Ng DS, *et al*. Reduced macular vascular density in myopic eyes. Chin Med J 2017;130:445-51.
17. Sakata K, Funatsu H, Harino S, Noma H, Hori S. Relationship between macular microcirculation and progression of diabetic macular edema. Ophthalmology 2006;113:1385-91.
18. Chin EK, Kim DY, Hunter AA, Pilli S, Wilson M, Zawadzki RJ, *et al*. Staging of macular telangiectasia: Power-Doppler optical coherence tomography and macular pigment optical density. Invest Ophthalmol Vis Sci 2013;54:4459-70.
19. Veverka KK, AbouChehade JE, Iezzi R Jr., Pulido JS. Noninvasive grading of radiation retinopathy: The use of optical coherence tomography angiography. Retina 2015;35:2400-10.
20. Wang SW, Hung KC, Tsai CY, Chen MS, Ho TC. Myopic traction maculopathy biomarkers on optical coherence tomography angiography-An overlooked mechanism of visual acuity correction in myopic eyes. Eye 2019;33:1305-13.
21. Imamura Y, Fujiwara T, Margolis R, Spaide RF. Enhanced depth imaging optical coherence tomography of the choroid in central serous chorioretinopathy. Retina 2009;29:1469-73.
22. Koçak N, Subaşı M, Yeter V. Effects of age and binarising area on choroidal vascularity index in healthy eyes: An optical coherence tomography study. Int Ophthalmol 2021;41:825-34.
23. Singh SR, Invernizzi A, Rasheed MA, Cagini C, Goud A, Vupparaboina KK, *et al*. Wide-field choroidal vascularity in healthy eyes. Am J Ophthalmol 2018;193:100-5.
24. Tang N, Zhao X, Chen J, Liu B, Lu L. Changes in the choroidal thickness after macular buckling in highly myopic eyes. Retina 2021;41:1858-66.
25. Ruiz-Medrano J, Flores-Moreno I, Ohno-Matsui K, Cheung CM, Silva R, Ruiz-Moreno JM. Validation of the recently developed atn classification and grading system for myopic maculopathy. Retina 2020;40:2113-8.
26. Quiroz-Reyes M, Andrade B, Quiroz-Gonzalez E, Quiroz-Gonzalez M, Kim H. Long-term postoperative structural and functional evaluation in myopic foveoretinal detachment. Int J Ophthalmol Clin Res 2021;8:132.
27. Quiroz-Reyes MA, Quiroz-Gonzalez EA, Quiroz-Gonzalez MA, Alsaber A, Lima-Gomez V. Long-term post-operative perfusion outcomes in giant retinal tears treated with and without scleral buckling. Lat Am J Ophthalmol 2022;5:1-13.
28. Klufas MA, Phasukkijwatana N, Iafe NA, Prasad PS, Agarwal A, Gupta V, *et al*. Optical coherence tomography angiography reveals choriocapillaris flow reduction in placoid chorioretinitis. Ophthalmol Retina 2017;1:77-91.
29. Kuehlewein L, Bansal M, Lenis TL, Iafe NA, Sadda SR, Filho MA, *et al*. Optical coherence tomography angiography of Type 1 neovascularization in age-related macular degeneration. Am J Ophthalmol 2015;160:739-48.e2.
30. Wei X, Mishra C, Kannan NB, Holder GE, Khandelwal N, Kim R, *et al*. Choroidal structural analysis and vascularity index in retinal dystrophies. Acta Ophthalmol 2019;97:e116-21.
31. Henkind P, Gartner S. The relationship between retinal pigment epithelium and the choriocapillaris. Trans Ophthalmol Soc U K 1983;103:444-7.
32. Tan R, Agrawal R, Taduru S, Gupta A, Vupparaboina K, Chhablani J. Choroidal vascularity index in retinitis pigmentosa: An OCT study. Ophthalmic Surg Lasers Imaging Retina 2018;49:191-7.
33. Todorova MG, Türksever C, Schötzau A, Schorderet DF, Valmaggia C. Metabolic and functional changes in retinitis pigmentosa: Comparing retinal vessel oximetry to full-field electroretinography, electrooculogram and multifocal electroretinography. Acta Ophthalmol 2016;94:e231-41.
34. Iovino C, Au A, Hilely A, Violanti S, Peiretti E, Gorin MB, *et al*. Evaluation of the choroid in eyes with retinitis pigmentosa and cystoid macular edema. Inves Ophthalmol Vis Sci 2019;60:5000-6.
35. Ratra D, Tan R, Jaishankar D, Khandelwal N, Gupta A, Chhablani J, *et al*. Choroidal structural changes and vascularity index in stargardt disease on swept source optical coherence tomography. Retina 2018;38:2395-400.
36. Koh LH, Agrawal R, Khandelwal N, Charan LS, Chhablani J. Choroidal vascular changes in age-related macular degeneration. Acta Ophthalmol 2017;95:e597-601.
37. Ng WY, Ting DS, Agrawal R, Khandelwal N, Htoon HM, Lee SY, *et al*. Choroidal structural changes in myopic choroidal neovascularization after treatment with antivascular endothelial growth factor over 1 year. Invest Ophthalmol Vis Sci 2016;57:4933-9.
38. Hwang BE, Kim M, Park YH. Role of the choroidal vascularity index in branch retinal vein occlusion (BRVO) with macular edema. PLoS One 2021;16:e0258728.
39. Kim RY, Chung DH, Kim M, Park YH. Use of choroidal vascularity index for choroidal structural evaluation in central serous chorioretinopathy with choroidal neovascularization. Retina 2020;40:1395-402.

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