Choroidal vascularity index: a step towards software as a medical device

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ABSTRACT

The choroidal vascularity index (CVI) is a relatively new parameter, calculated off optical coherence tomography (OCT) images, for the quantitative evaluation of choroid vascularity. It is defined as the ratio of vascular area to the total choroidal area, presented as a percentage. The choroid is an important vascular bed, often implicated in ocular and systemic conditions. Since the introduction of CVI, multiple studies have evaluated its efficacy as a tool for disease prognostication and monitoring progression, with promising results. The CVI was born out of the need for more robust and accurate evaluations of choroidal vasculature, as prior parameters such as choroidal thickness and choroidal vessel diameter had their limitations. In this review, we summarise current literature on the CVI, explain how the CVI is derived and explore its potential integration into future research and translation into clinical care. This includes the application of CVI in various disease states, and ongoing attempts to produce an automated algorithm which can calculate CVI from OCT images.

INTRODUCTION

The choroid is a highly vascularised structure that serves primarily to nourish the outer one-third of the retina, delivering its oxygen supply at high flow.[1] It is located between the retinal pigmental epithelium (RPE)-Bruch's membrane complex and the sclera and comprises three vascular layers. The choriocapillaris is the innermost choroidal layer followed by Sattler's layer and Haller's layer. Haller's layer contains the largest vessels, which provide the main arterial supply and venous drainage. The choroidal circulation is altered pathologically in various ocular diseases, including age-related macular degeneration (AMD), diabetic retinopathy (DR) and central serous chorioretinopathy.[2–7] Objective evaluation of structural changes in the choroidal vasculature will offer insights and characterisation of normal variations and disease extent and progression, which may be useful in clinical management and prognostication. In this review, we will summarise the current literature on the choroidal vascularity index (CVI), a promising optical coherence tomography (OCT)-based biomarker used to quantitatively assess choroidal health, explain how the CVI is derived and explore its potential integration into future research and translation into clinical care.

STRUCTURAL ANALYSIS OF CHOROIDAL VASCULATURE

Traditionally, structural analysis of the choroidal vasculature has been technically challenging due to its physical inaccessibility. Recent advances in imaging technology have allowed improved visualisation of choroidal structure; however, limitations remain (table 1). Enhanced depth imaging using OCT has been widely adopted because it offers non-invasive, rapid image acquisition while providing high resolution visualisation of small vascular changes in the choroidal structure. On an OCT image, the choroid is represented by a light grey strip, interspersed with cross-sectional vascular lumena, which appear as hyporeflective regions. The choroid's inner border is marked by the hyper-reflective RPE-Bruch's membrane complex, while its outer border is marked by the choroidal-scleral interface (CSI). Specific structural analysis requires a technique that can reliably demarcate and quantify the individual choroidal components. A numerical parameter dedicated to the quantitative assessment of these choroidal vascular components would be useful for research purposes and for clinical assessment. Objective biomarkers would facilitate reproducible and reliable measurements, allowing documentation of the effects of ageing on the choroid as well as pathological processes and response to pharmacological intervention.

Three OCT-based quantitative surrogate markers have been employed to estimate choroidal health. These include choroidal thickness (CT), CVI and choroidal vessel diameter. Our group has developed and validated the tool of CVI in diseases affecting the retina and choroid. CT is defined as the perpendicular distance from the CSI to the outer edge of the hyper-reflective RPE-Bruch's membrane complex. CT has been documented to vary significantly with age, sex and refractive error[8] and is also sensitive to segmentation errors.[9] This variability contributes to poor reproducibility. Studies documenting CT in eyes with AMD have reported inconsistent results in CT.[10–14] Furthermore, measuring CT does not reveal the exact choroidal component affected by a disease of interest, given that the choroid is composed of vessels embedded in a stroma of connective tissue, melanocytes, nerves and extracellular fluid. Choroidal vessel diameter has been proposed as another choroidal imaging parameter,[15] defined as the diameter

Table 1 Current methods of choroidal visualisation

Modality	Advantages and limitations
Histopathology	▶ Requires biopsied samples with interventional risks. ▶ Postfixation shrinkage and sample distortion reduces reproducibility of results.
Ultrasonography	▶ Readily available in most clinical settings. ▶ Insufficient resolution to visualise alterations in narrow vessel structure. ▶ Dependent on operator skills.
Angiography with fundus fluorescein or indocyanine green (ICGA) dyes	▶ ICGA is the historical gold standard for choroidal structural and functional evaluation. ▶ Invasive and time consuming. ▶ Intravenous dye usage may be contraindicated in selected patients. ▶ Unable to individually evaluate the choroidal layers.
Optical coherence tomography (OCT)	▶ Non-invasive, fast image acquisition, high-resolution. ▶ Generates volumetric data for qualitative and quantitative analysis. ▶ Has various models/modes to enhance image quality.
OCT angiography	▶ Generates three-dimensional angiographic maps using sequential OCT B-scans to visualise blood flow. ▶ Provides adjustable depth to examine anatomical layers of the retina and choroid.

of the largest intrachoroidal hyporeflective region, that would presumably be the largest vessel diameter and may be used to estimate the degree of vascular engorgement. However, it remains unclear if a single vessel diameter is adequately representative of the entire choroidal vasculature.

CVI is a novel OCT-based parameter proposed in 2016 by Agrawal *et al*,[8] defined as the ratio of vascular luminal area (LA) to total choroidal area (TCA) and is presented as a percentage.

$$CVI = \frac{Vascular\ LA}{TCA}$$

CVI is calculated from OCT scans via image binarisation, a technique first applied for this purpose by Sonoda *et al*.[16] In short, image binarisation quantifies pixel intensities within a grey scale image, while accounting for the illumination, contrast and resolution of all pixels. This information is used to delineate vessel lumena (dark), stroma (light) and the RPE-Bruch's membrane border (very bright), eventually facilitating calculation of LA and TCA. The parameter developed by Sonoda *et al* was termed 'choroidal vascular ratio' (LC ratio).[16] A comparative study has shown that the LC ratio tends to provide a smaller estimate of choroidal vascularity than CVI, likely because of technical variations in the derivation protocols.[17] CVI may be more accurate in delineating the choroid, due to binarisation prior to image segmentation. The clinical standing of both parameters will benefit from further investigations to assess their suitability in quantifying choroidal vascularity.

CALCULATING CVI

The CVI can be calculated from OCT images manually or via an automated algorithm. The latter is available in the online, secured image analysis platform (www.ocularimaging.net) and is currently being validated. While manual calculation is time-consuming and impractical for large-scale analysis, it forms the basis of the automated process. The subfoveal choroidal area was selected as the region of interest (ROI), defined as a single line within the macula, centred at the fovea, with a width of 1.5 mm. It was important to prespecify a constant ROI due to the segmental nature of the choroidal blood supply.[18] Comparison of CVI obtained from three different ROIs—subfoveal, central macular and total macular scans reported no significant difference in the final CVI obtained in healthy eyes.[19] CVI may not be affected by the OCT machine algorithm, whether swept-source or spectral-domain.[20]

Manual analysis

While developing the CVI, Agrawal *et al*[8] experimented with Otsu's, Bernsen's and Niblack's thresholding techniques. Simply, thresholding techniques convert an image from colour or greyscale into a binary image, which has only black and white pixels. Thresholding is used for image segmentation—selecting areas of relevance within an image while ignoring the parts that are not of interest. Niblack's autolocal threshold technique was chosen because it accounted for the mean and SD of all pixels in the ROI.[8] The variation in melanin content of the RPE among different eyes and the possibility of suboptimal image focus were also considered. Image binarisation into black and white pixels provided a clear view of the CSI as a line of white pixels, which is advantageous in allowing more precise delineation of the subfoveal choroid for TCA calculation. On the black and white image in figure 1, the TCA was manually selected using the upper border, marked by the RPE-Bruch's membrane complex, whereas the lower border is marked by the CSI. Once the software registers this manually selected ROI, red-green-blue colour conversion is implemented to find the LA, which appears as central areas of dark pixels resembling vascular lumen. CVI is calculated via dividing LA by TCA as described above. The final binarised image can be overlaid onto the original image for verification and ease of interpretation (figure 1).

Automated analysis

Broadly, an automated algorithm for CVI calculation would need to execute three major steps—choroidal segmentation on images, detection of choroidal vessels and area computation.

The following briefly describes the automated algorithm protocol for CVI calculation in a stepwise manner, with a visual example in figure 2:

1. Preprocessing: unwanted segments of the image are masked; greyscale conversion is implemented with increased contrast.
2. Binarisation: Niblack's autolocal threshold is applied.
3. Boundary detection: superior boundary is the RPE (bright band), while the inferior boundary is the CSI. The binarised image is scanned horizontally to obtain the RPE height and at various intervals. The CSI is generally clearer to demarcate. The area superior to the RPE and inferior to the CSI is subsequently neglected.
4. Vascular LA detection: opening and closing is performed. Some definitions—opening refers to erosion followed by dil-

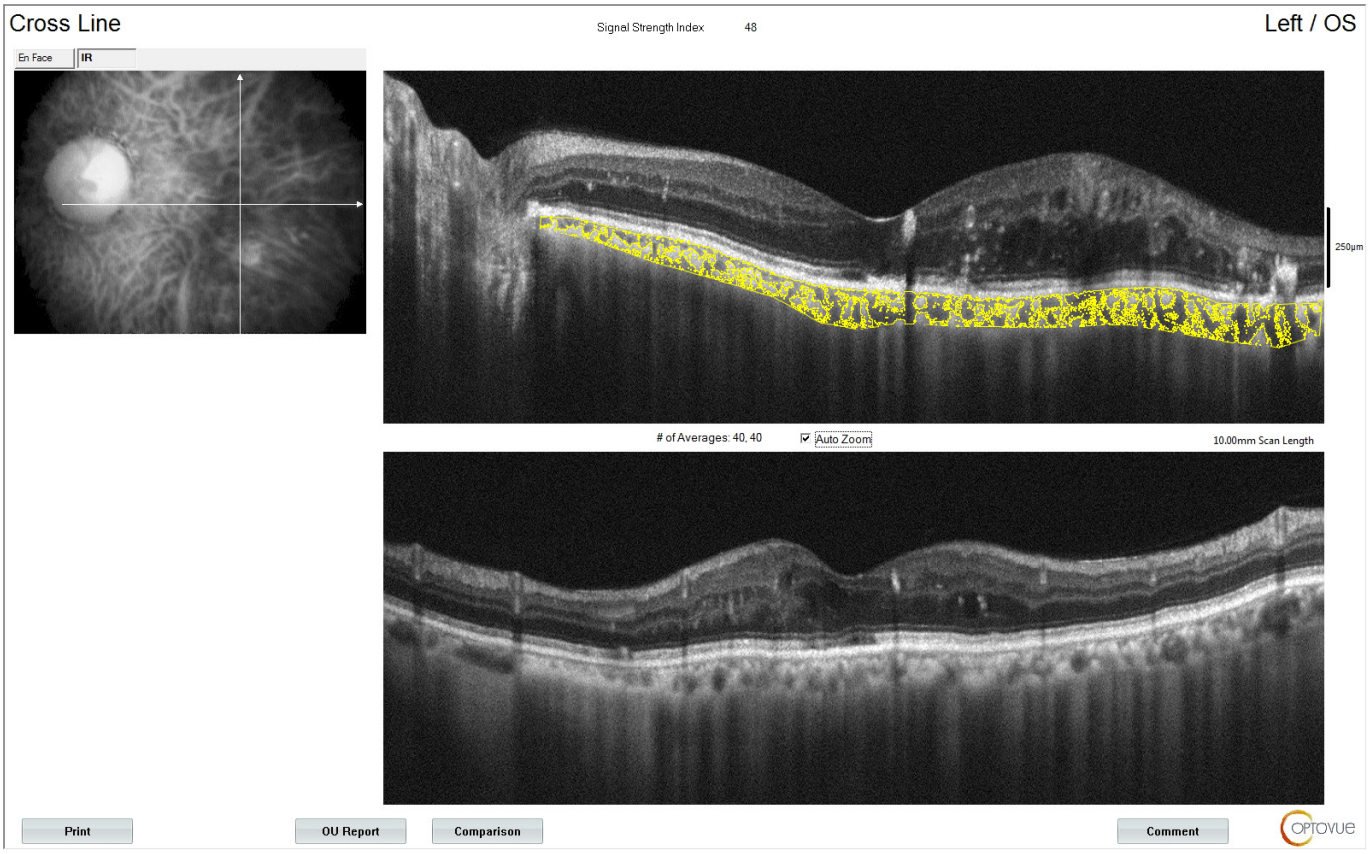

Figure 1 Overlay of the binarised choroid over the original optical coherence tomography B-scan of a patient with diffuse macular edema.

atation while closing refers to dilatation followed by erosion (vice versa). Erosion and dilatation are two fundamental image processing operations. Dilation adds pixels to the boundaries of objects in an image. In a binary image, a pixel is set to 1 if any of the neighbouring pixels have the value 1. Conversely, erosion removes pixels on object boundaries; a pixel is set to 0 if any of the neighbouring pixels have the value 0.

5. The original image is subtracted from this processed image to highlight the LA.
6. Noise reduction: noise is reduced by opening and closing, and thresholding using the average of all pixels. Contours are detected in the image and small contours are removed.
7. LA is overlaid onto the binarised image and CVI is calculated.
8. Manual adjustment of the ROI: the detection accuracy of the desired ROI depends on image factors (quality, contrast and edge segmentation) and infrastructure factors (OCT scanning machine configuration and capabilities). Depending on

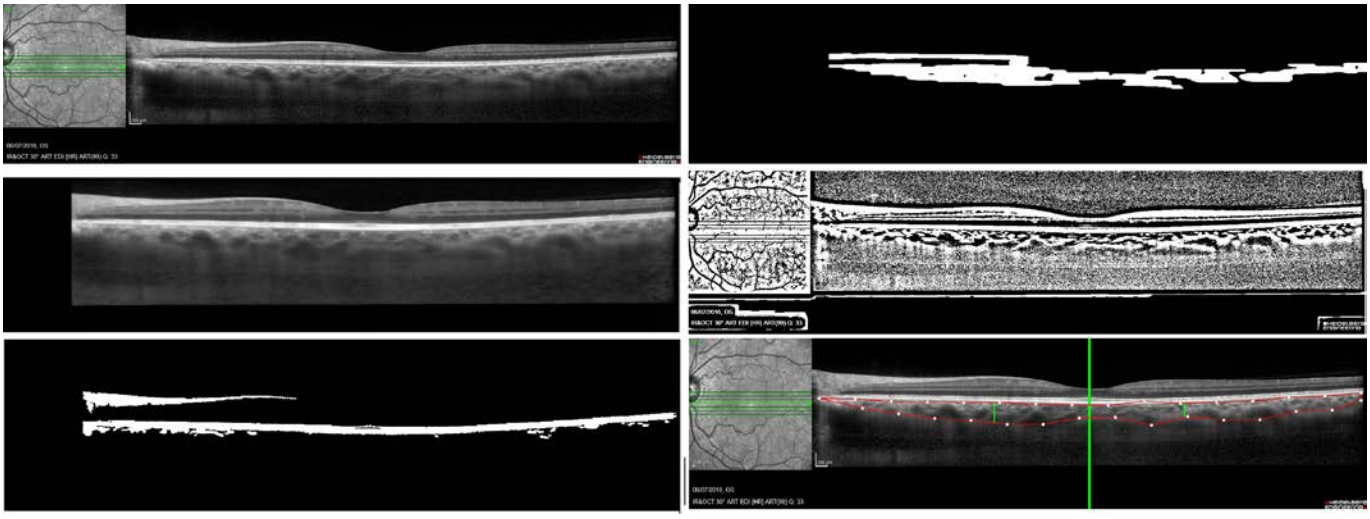

Figure 2 Workflow of the automated algorithm. (Left upper) original image; (left middle) unwanted parts and noise removed; (left lower) retinal pigment epithelium and choroidal-scleral interface boundary detection; (right upper) detection of vascularised areas; (right middle) final binarised image result; (right lower) gross application of image using Niblack's autolocal threshold.

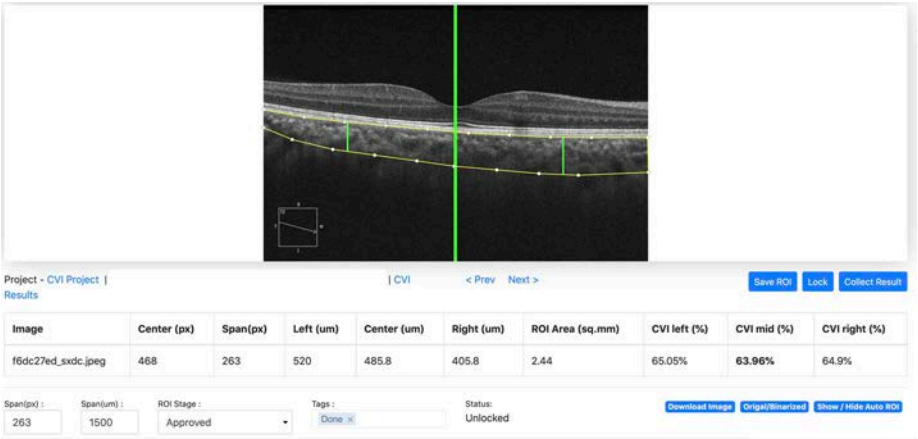

Figure 3 Example of the end user interface with overlaid adjustment handles to edit the machine-detected region of interest (ROI). The span area can be adjusted to the area of interest with displayed choroidal vascularity index (CVI) and choroidal thickness (CT) values for the selected central region and for the regions on left and right of central region.

these variables, there will be a need for correction of ROI and aligning it accurately with the choroidal boundaries. The end user is presented with an interactive interface allowing manual adjustment of the ROI if necessary, to accommodate scans of different widths other than the central macular area of 1500 μm (figure 3).

CURRENT UTILISATION OF CVI AS A CLINICAL AND RESEARCH TOOL

CVI has proved to be a reliable OCT-based tool for choroidal structure analysis.[8 19–21] Since its introduction, studies have attempted to characterise baseline values in the healthy choroid. A 2016 study[8] on Singapore's Malay population estimated that a normal CVI was approximately 65.6%±2.3% in healthy individuals, suggesting that about two-thirds of the normal subfoveal choroidal volume is vascular. Compared with CT (an older parameter of choroidal vascularity), CVI had a lower covariance and was not associated with patient factors such as age, systolic blood pressure, axial length or intraocular pressure.[8] In addition, there is no significant effect on CVI measurements regardless of the type of OCT machine used (swept-source vs spectral domain),[20] and the retinal area at which scans are taken (subfoveal, total macular or central macular),[19] demonstrating that CVI could be a versatile OCT parameter that is resistant to changes in other physiological parameters, which could potentially confound results. Further work is needed to evaluate the association (if any) between CVI and ocular parameters, such as refractive error and lens thickness.

Repeatable findings also have been obtained by groups that calculated the CVI in various sight-threatening ocular and systemic illnesses.[12 21–32] table 2 broadly summarises the findings and applications of CVI in current literature. Cigarette smoking was identified as a factor that compromises choroidal vasculature in healthy subjects[33] (65%±2% in smokers vs 67%±2% in non-smokers, p=0.0001), associated with a pack year-dependent reduction in CVI (0.12% per pack year). A small cross-sectional study explored the diurnal variations of CVI in healthy individuals, which exhibited significant differences between maximum and minimum individuals through the day.[34]

Age-related macular degeneration

With regard to disease states, CVI has established significantly reduced choroidal vascularity in AMD, suggesting choroidal ischaemia, which is a risk factor for subsequent choroidal neovascularisation.[22 35] While choroidal involvement in AMD has been proven in the past by histological studies,[3 4 21] structural analysis based on CT changes were inconclusive.[12 13] The introduction of CVI has allowed a more complete understanding of the pathological changes of the choroid in AMD. Giannaccare *et al*[36] showed that a decreased CVI could be related to the development of geographic atrophy; CVI was significantly reduced, along with SFCT and stromal area.[36] In monocular AMD, Wei *et al*[24] found that affected eyes had a significantly lower CVI than the contralateral healthy eye, but changes in SFCT were insignificant, perhaps because of increased stromal content. To accompany this finding, Koh *et al*[22] found that patients with monocular AMD tended to have reduced CVI in their contralateral, non-diseased eyes. This result hints at subclinical disease with some choroidal ischaemia, possibly indicating a risk of future clinically significant AMD. While such patients may potentially benefit from close monitoring and preventive measures, further longitudinal studies using CVI are required to evaluate this conjecture.

Diabetes mellitus and diabetic retinopathy

The increased global prevalence of diabetes mellitus (DM) has been accompanied by increased rates of DR, one of its more common complications. Besides retinal changes, DM causes pathological choroidal changes including capillary dropout, luminal narrowing, choroidal neovascularisation and vascular remodelling with increased tortuosity.[6] Measurement of SFCT at various stages of DR has provided inconsistent findings,[37–39] possibly because the various stages of DR have an unequal effect on different choroidal components, which cannot be holistically assessed with SFCT. In contrast, CVI has been shown to be significantly reduced in DM, providing quantitative evidence of diabetic choroidopathy, and is reported to progressively worsen with increased clinical severity of retinopathy.[29 40 41] However, CVI was not associated with haemoglobin A1c readings, fasting blood glucose levels or disease duration. In a 2018 study, Kim *et al*[40] reported that eyes with proliferative DR exhibited the

Table 2 An overview of CVI studies in current literature

Study	Country	Results/Findings
Koh *et al*[22]	India	OCT scans of 64 patients with unilateral or bilateral AMD were obtained. Foveal scans of 63 AMD eyes and 35 contralateral healthy eyes were analysed. Images of 30 eyes from 18 age-matched healthy subjects were included as controls. CVI in AMD, contralateral healthy eyes and controls was 64.04%±2.43%, 64.66%±2.25% and 66.07%±1.72%, respectively. CVI was significantly reduced in AMD and fellow healthy eyes.
Wei *et al*[24]	Singapore	Eyes with exudative AMD demonstrated significantly reduced CVI (60.14±4.55 vs 62.75±4.82, p<0.01) compared with their fellow eyes but insignificant differences in SFCT.
Wei *et al*[33]	Singapore	CVI in smokers (65%±2%) was lower compared with non-smokers (67%±2%, p=0.0001). The difference remained significant after adjusting for age (p=0.001). CVI decreased by 0.12% with each unit increase in smoking measured by pack year (p=0.0009). Cigarette smoking is associated with decreased choroidal vascularity in healthy subjects, and this association appears to be dose dependent.
Bakthavatsalam *et al*[25]	Hong Kong, China	After adjusting for age, axial length, and gender in multivariate regression analysis, the SFCT of PCV and neovascular AMD eyes were not significantly different from healthy eyes (195.55±93.11 µm), but the CVI of both PCV (64.94%±5.43%, p=0.01) and neovascular AMD (62.54%±5.57%, p≤0.01) were significantly lower than control (68.53%±5.91%).
Invernizzi *et al*[23]	Italy	Mean CVI significantly increased with active disease in nAMD eyes from 54.5%±3.3% to 55.4%±3.8% (p=0.04). Changes in choroidal thickness may predict CNV development or recurrence before they are otherwise evident clinically.
Liu *et al*[49]	China	Among polypoidal choroidal vasculopathy patients, the CVI in eyes with choroidal vascular hyperpermeability was significantly greater than that in those without CVH (65.78±4.70 vs 62.28±3.90; p=0.002).
Giannaccare *et al*[36]	Italy	OCT scans of 34 patients with GA and 32 control subjects were retrospectively analysed. Data were collected at baseline and after a mean follow-up of 18.3±8.3 months. Patients with GA showed significantly lower values of CVI, total choroid area, luminal area and subfoveal choroidal thickness compared with control subjects (65.83±3.95 vs 69.33±3.11, p<0.001; 0.400±0.239 mm vs 0.491±0.132 mm, p=0.006; 0.263±0.152 mm vs 0.340±0.094 mm, p=0.002; 185.2±79.8 µm vs 216.8±58.8 µm, p=0.036, respectively). This study showed for the first time that CVI is reduced in patients with GA, and that this metric further worsened during the follow-up period.
Tan *et al*[41]	Singapore	Eyes of patients with DM showed significantly lower CVI as compared with controls (65.10±0.20 vs 67.20±0.16, p<0.0001) with no corresponding change in choroidal thickness. CVI was also reduced in DR compared with DM without DR. Image binarisation may be useful to assess choroidal structures and vasculature.
Kim et al[40]	South Korea	The eyes of patients with DM exhibited a significantly lower CVI value than those of healthy controls, even without DR (66.10±3.03 vs 69.08±2.29, p<0.001). There was progressive reduction in CVI with DR progression. In multivariate regression analysis, thicker subfoveal choroid and thinner central retina were significantly associated with higher CVI values.
Okamoto *et al*[50]	Japan	The most significant reduction in CVI was observed following intravitreal ranibizumab for patients without previous PRP. CVI and choroidal blood flow were significantly reduced only in the no-PRP group and not in the PRP-treated group.
Gupta et al. (2018)[29]	Singapore	A cross-sectional study was conducted on 82 eyes with DR and DME and 86 healthy control eyes. CVI may be a more accurate surrogate marker for DME and DR and can potentially be used to monitor the progression of DR. CVI was significantly decreased in DME with DR eyes as compared with controls (63.89±1.89 vs 67.51±2.86, p<0.001). CVI was also significantly decreased with worsening DR (mild NPDR=66.38±0.3, moderate NPDR=65.28±0.37, severe NPDR=63.50±0.47, PDR=61.27±0.9, p<0.001).
Kim et al. (2019)[28]	South Korea	Significant association between systemic arterial stiffness and CVI. After adjustment for possible confounding factors, cardio-ankle vascular index showed a negative correlation with the CVI (r=−0.247, p=0.013).
Park et al. (2018)[32]	South Korea	The CVI of eyes with MvD were significantly lower than those without MvD, globally (60.76±64.22 vs 62.95±64.30, p=0.010) as well as in the inferotemporal (p=0.003), temporal (p=0.009) and nasal (p=0.048) sectors.
Park et al. (2019)[31]	South Korea	CVI of both OAG (64.34%±0.19%, p=0.001) and PPG (65.37%±0.15%, p=0.001) were significantly lower than healthy eyes (68.81%±0.14%).
Chen et al. (2018)[27]	China	Phacoemulsification induced increased CVI in patients diagnosed with cataract. The mean CVI at baseline was 60.1%±5.5%. After phacoemulsification surgery, the CVI significantly increased to 61.7%±5.3% at D7, 63.6±4.4% at 1 month postoperatively and 64.8%±4.0% at 3 months postoperatively (p=0.035, 0.0006, <0.0001, respectively). Univariate and multiple regression analysis revealed a positive association between CVI and SFCT at pre-operation and no significant association with age, axial length, intraocular pressure (IOP) and gender at all timepoints. Evaluation of the long-term change of CVI following surgery may provide valuable information for studying the relationship between phacoemulsification and disorders of the choroid.
Yip et al. (2019)[26]	Singapore	The baseline CVI was significantly lower in patients with diabetes for both operated (mean difference vs non-diabetic: 0.0184, 95% CI 0.004 to 0.0324, p=0.012) and non-operated (mean difference vs non-diabetic: 0.0145, 95% CI 0.003 to 0.0256, p=0.012) eyes. Increased CVI following phacoemulsification was not significant following Bonferroni adjustment. No difference in CVI between diabetes and healthy controls following surgery. *DM*: baseline 65.50%±2.40%, 1 month 67.00%±2.30%, 3 months 67.00%±3.10%. *Control*: baseline 67.30%±1.70%, 1 month 67.50%±1.70%, 3 months 67.70%±1.40%.

AMD, age-related macular degeneration; CVI, choroidal vascularity index; DM, diabetes mellitus; DME, diabetic macular edemaoedema; DR, diabetic retinopathy; MvD, parapapillary deep layer microvascular dropout; OCT, optical coherence tomography; PPG, preperimetric glaucoma; PRP, pan retinal photocoagulation; SFCT, subfoveal choroidal thickness.

lowest CVI, which suggests more severe choroidal ischaemia that is a precursor to retinal neovascularisation. In patients with diabetes, after adjustment for possible confounding factors, cardio-ankle vascular index showed a negative correlation with the CVI (r=−0.247, p=0.013),[28] suggesting that choroidal vascular degeneration in diabetes might be related to systemic

atherosclerosis. Available literature on the relationship between CVI and diabetic macular oedema have shown mixed results.[29 40] A recent study by Gupta *et al*[29] which had a large sample size found that CVI was significantly decreased in diabetic macular oedema compared with controls (63.89%±1.89% vs 67.51±2.86%, p<0.001). Hence, CVI has demonstrated potential as a quantitative marker to monitor the progression of DR. It may be worthwhile to consider CVI as an adjunct to retinal photography in the regular clinical assessment of patients with DM.

Applications of CVI in other diseases and procedures

CVI has also been used to monitor ocular inflammatory and infectious diseases. Kim *et al* reported increased CVI in HLA-B27-positive anterior uveitis.[42] CVI has been shown to be diminished in tubercular multifocal serpiginoid choroiditis, in which lesions develop in a serpentine fashion, often bilateral with chronic choroidal inflammation.[43] In panuveitis, initially elevated CVI was found in eyes suffering from panuveitis,[44] which declined over a 3-month follow-up. For uveitis cases in which corticosteroid therapy might be indicated, treatment response could possibly be monitored via CVI, which quantifies choroidal vascular changes over time. This approach might decrease the risk of overtreatment or undertreatment with corticosteroids.

With regard to interventional procedures, inflammation from surgical trauma can cause choroidal thickening postphacoemulsification.[45] Chen *et al*[27] documented a gradual increase in CVI up to 3 months postoperatively, accompanied by increased CT. It was suggested that a disrupted blood-aqueous barrier allowed inflammatory mediators from the aqueous to enter the vitreous and choroid, inducing structural changes that expanded the choroidal vascular area following phacoemulsification. Another study compared CVI measurements in patients with diabetes and healthy patients undergoing phacoemulsification.[26] Patients with diabetes had significantly lower CVI than patients without diabetes at both the pre-operative and postoperative timepoints. Reduced choroidal vascularity might contribute to poorer visual recovery in patients with diabetes following surgery.

LIMITATIONS OF CVI

Like any new screening modality, CVI comes with its own set of imperfections. First, existing literature shows that many studies were conducted in Asian populations, with small sample sizes and short follow-up periods. Hence, the true applicability of CVI in the multiethnic global population awaits investigation. Such problems are understandable, however, as CVI has only emerged as a research subject in recent years. With growing awareness, we expect future studies to be more clinically rigorous, with longer follow-up periods and larger sample sizes from diverse ethnic and geographic populations. CVI calculation is dependent on OCT image quality. If the CSI cannot be defined, then CVI calculations are not reliable. For instance, the retinal blood vessels may cast shadows that affect visualisation of the choroid during posterior segment OCT imaging. The visualisation technique of shadow compensation has been suggested to improve choroidal visualisation,[46] but more data are necessary to validate this approach. Other challenges may include compromised image resolution due to highly myopic eyes, opacities, eye movements and the presence of pathological changes which distort choroidal visualisation.

CONCLUSIONS

Considering the global ageing population, public health authorities have reiterated the concept of 'healthy ageing'—growing old with full functional and cognitive independence while maintaining a normal quality of life. Reducing visual impairment contributes to an improved quality of life and increase in number of disability-free life years in a multifactorial manner.[47] Given that profound visual loss significantly impairs one's psychological well-being,[48] it is important to preserve the vision of at-risk patients to reduce disability and maintain functional independence. Ideally, ocular screening modalities aim to accurately identify progression or development of visual impairment, without compromising practicality and cost-effectiveness. The CVI is an emerging OCT-based parameter that can potentially be incorporated, at very low cost, into existing OCT machines, or with separate evaluation on downloaded OCT scans. With the emergence of automated artificial intelligence technology, CVI holds promise as an adjunctive assessment tool for patients at risk of visual impairment. More studies of the effective implementation of CVI for mass screening purposes are warranted.

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