Comparison of choroidal thickness between amblyopic and non-amblyopic eyes

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INTRODUCTION

Amblyopia is a condition characterized by unilateral or bilateral reduced visual acuity even with optimum refractive correction and in absence of other pathological diseases (Rouse, 2004). Depending on the etiology, amblyopia is classified into strabismus, form deprivation and anisometropia. It is ascertained that amblyopia occurs as a result of morphological changes to the lateral geniculate nucleus and the visual cortex during infancy and early childhood (Campos, 1995; Moss, 2005). A number of studies have investigated the retinal nerve fibre layer thickness (Wu et al., 2013; Yen et al., 2004) and retinal thickness (Pang et al., 2015) in the eyes of amblyopia. However, there has been dispute between those studies regarding involvement of the retina in amblyopia.

Recent studies suggest that the choroid may play a role in the regulation of refractive state and maybe involved in the emmetropization process. Choroid is one of the most vascularized pigmented structures of the eye that lies between the retina and sclera. It is mainly responsible to deliver nutrition and oxygen to the retina and pigmented structures of the eye that lies between the retina and sclera.

Choroidal thinning respectively. The existing bodies of research on the ability of the choroid to modulate its thickness in the eyes of these animal models raised the possibility if the same phenomenon occurs in humans.

The anatomy of the choroid has been studied extensively in the normal eyes of human (Agawa et al., 2011; Chhablani et al., 2014; Coşkun E1 et al., 2014; Ding et al., 2011; Ruiz-Moreno et al., 2013). In normal eyes, the choroid was reportedly reduced in thickness with increased degree of myopia (Jin et al., 2016). However, only a limited number of studies have examined choroidal thickness in adults and children with amblyopia (Aygit et al., 2015; Kantarci et al., 2015; Nishi, Ueda, Hasegawa, Miyata, & Ogata, 2014; Tenlik et al., 2014). The non-invasive optical coherence tomography with enhanced depth imaging technique allows high resolution visualization of the choroid in those studies (Aygit et al., 2015; Kantarci et al., 2015; Mori, Sugano, Maruko, & Sekiryu, 2014; Nishi et al., 2014; Tenlik et al., 2014; Xu et al., 2014). Those studies which predominantly determined choroidal thickness in strabismus and hyperopic anisometropic amblyopia found thicker choroid in the amblyopic eyes compared with the fellow eyes or controls.

However, research to date has not yet determined the choroidal thickness in children with myopic anisometropic amblyopia. Our study aimed to determine the anatomical profile of the choroid in myopic anisometropic amblyopia using the spectral domain optical coherence tomography (SD-OCT) with enhanced depth imaging.
The choroidal profile of the amblyope was examined and compared with the fellow non-amblyopic eyes in a cross-sectional study design. Measurements of choroidal thickness were made within 6 mm macular area using spectral-domain optical coherence tomography, supplemented with enhanced depth imaging technique. Reduced choroidal thickness presented in the eyes with amblyopia by the ETDRS topography map would indicate different choroidal profile of the amblyope from the normal.

Choroidal thickness was measured in five myopic anisometropic amblyopes who were recruited from Hospital Selayang. All subjects were follow-up patients diagnosed with anisomyopic amblyopia in the hospital. Ethics approval was obtained from the UiTM research ethics committee and the Medical Research & Ethics Committee (MREC) in accordance to the ICH Good Clinical Practice Guidelines and the Declaration of Helsinki. Written informed consent was obtained from the child’s parent or legal guardian before the participation.

**RESULTS AND DISCUSSION**

The mean best corrected visual acuity of the amblyopic eyes and the fellow eyes were 0.94 (± 0.27) and 0.14 (± 0.05) logMAR respectively. The mean spherical equivalent of the amblyopic eyes was -1.20 (± 0.41) D, which was more myopic than the fellow eyes (-1.40 ± 2.05 D). The amblyopic eyes had longer axial length (26.46 (± 0.44 mm) compared to the fellow eyes (23.59 (± 1.18 mm)). The subfoveal choroidal thickness of the amblyopic eyes was much thinner (124.30 µm) compared with the fellow eyes (246.80 µm). In the amblyopic eyes, the choroid was thinnest in the nasal region followed by the temporal, inferior, and superior regions. The horizontal and vertical distribution of the choroid in the amblyopic eyes was different from the fellow non-amblyopic eyes.

Choroidal imaging and segmentation

The images of the choroid of the anisomyopic eyes were obtained by Heidelberg Spectralis Optical Coherence Tomography (Heidelberg Engineering, Heidelberg, Germany) using enhanced depth imaging (EDI-OCT) technique. In order to avoid diurnal variations of the choroidal thickness, all examinations were performed between 12:00 to 15:00. The OCT scans were performed by 2 examiners independently using the built-in segmentation of the RPE and the chorioscleral border. Manual segmentations of the RPE and the chorioscleral border of each image were performed by 2 examiners independently using the built-in Heidelberg Eye Explorer software (version 1.5.12.0; Heidelberg Engineering). The manual segmentation of the choroid was performed by moving the line on internal limiting membrane layer to the RPE, and the line on Bruch membrane to the chorioscleral border for each 25 horizontal scan. Complete segmentation of the 25 horizontal scans automatically altered the retinal thickness displayed on the ETDRS grid to choroidal thickness. The average of all points within the 1 mm central circle represented the subfoveal choroidal thickness.

**EXPERIMENTAL**

The mean best corrected visual acuity of the amblyopic eyes and the fellow eyes were 0.94 (± 0.27) and 0.14 (± 0.05) logMAR respectively. The mean spherical equivalent of the amblyopic eyes was -1.20 (± 0.41) D, which was more myopic than the fellow eyes (-1.40 ± 2.05 D). The amblyopic eyes had longer axial length (26.46 (± 0.44 mm) compared to the fellow eyes (23.59 (± 1.18 mm)). The subfoveal choroidal thickness of the amblyopic eyes was much thinner (124.30 µm) compared with the fellow eyes (246.80 µm). In the amblyopic eyes, the choroid was thinnest in the nasal region followed by the temporal, inferior, and superior regions for the 3 mm and 6 mm diameter macular areas (Fig. 1). The choroidal thickness for each of the macular subfield within the 3 mm diameter parafoveal region in the amblyopic eyes was 122.00 (± 39.23) µm in the nasal, 138.20 (± 53.64) µm in the inferior, 141.90 (± 54.01) µm in the superior, and 144.70 (± 52.66) µm in the temporal. For the 6 mm parafoveal region, the choroidal thickness of the amblyopic eyes was 93.75 (± 33.04) µm in the nasal subfield, 136.60 (± 63.59) µm in the inferior subfield, 145.30 (± 47.09) µm in the superior subfield and 148.50 (± 49.46) µm in the temporal subfield. The choroidal thickness for the nasal, temporal, inferior and superior 3 mm parafoveal subfields in the fellow eyes was 203.10 (± 38.40) µm, 245.20 (± 53.55) µm, 218.40 (± 48.18) µm and 250.10 (± 59.27) µm respectively. For the 6 mm parafoveal region, the choroidal thickness of the fellow eyes was 146.40 (± 25.61) µm in the nasal subfield, 231.50 (± 51.86) µm in the temporal subfield, 191.70 (± 36.80) µm in the inferior subfield and 243.20 (± 38.92) µm in the superior subfield.

Overall, the choroid was thinner in the amblyopic eyes at all parafoveal and perifoveal macular subfields than the fellow non-amblyopic eyes. The horizontal and vertical distribution of the choroid in the amblyopic eyes was different from the fellow eyes. The choroid reduced in thickness horizontally from the temporal quadrant to the nasal quadrant in the amblyopic eyes. However, the choroid was the thickest in the fellow non-amblyopic eyes at the subfoveal area followed by the temporal region and the nasal region. The vertical choroidal profile in the amblyopic eyes was also different from the fellow eyes. In the amblyopic eyes, the choroid was thinnest at the subfoveal area but thicker in the superior and inferior subfields. The 3 mm parafoveal and 6 mm perifoveal regions. For the fellow eyes, the choroid was thinner at the inferior 3 mm and 6 mm diameter subfields than the superior regions.

**Fig. 1** The average choroidal thickness profile of the amblyopic eyes and fellow eyes in horizontal (A) and vertical (B) meridians.
Our findings suggested that the choroidal thickness profile of the amblyopic eyes was different from the non-amblyopic eyes. The amblyopic eyes were found to have thinner choroid in all regions of the macular subfields compared with the fellow eyes. Our findings seemed to be consistent with what have been postulated earlier in animal studies. In a study on young monkeys, choroidal thickness was reported to change rapidly to compensate changes in the effective refractive state (Hung et al., 2000). The choroid thickened in response to imposed myopic defocus, but thinned in response to imposed hyperopic defocus in order to adjust the position of the retina to maintain clear vision. Following several lines of evidence from other animal studies, it was postulated that other than nourishing the retina, the choroid was also involved in the regulation of the refractive state in the early life of the humans (Hung et al., 2000; Troilo et al., 2000; Wildsoet & Wallman, 1995). If the same mechanism occurred in human eyes, a myopic defocus would be expected to cause the choroid to thicken as in the animal eyes. Choroidal thickness of children with hyperopic anisometropic amblyopia was found to be thicker in the amblyopic eyes than that of the fellow eyes and controls using optical coherence tomography (Nishi et al., 2014). In that study they hypothesized that in young children, hyperopic defocus caused choroidal thinning in the fellow eyes and control eyes but the choroidal compensation did not occur in amblyopic eye hence the choroid was found thicker. Our findings of thinner choroid in the amblyopic eyes than the fellow eyes might suggest that the choroid was unalbe to compensate the myopic defocus in anisomyopic amblyopic eye. Our amblyopic eye data displayed a horizontal distribution pattern of a choroid that was thickest at the temporal region, followed by the subfoveal, and nasal region where it was thinnest. The choroid in the fellow eyes on the other hand was thickest in the subfoveal area, followed by the temporal and nasal region. The choroidal profile of the fellow eyes were in agreement with those obtained previously from normal children’s eyes (Flores-Moreno et al., 2013; Ruiz-Medrano et al., 2014). The choroid was reported to be thickest at the subfoveal area, followed by the temporal region and was thinnest at the nasal region (Chui, Zhong, and Burns, 2011). They believed that the choroid was thinner nasally due to the adjacent location to the optic nerve head where the choroid was most susceptible to chorioretinal stretching during axial elongation in myopia development (Chui et al., 2011). Thinner choroid was reported in all regions of 7 to 10 year-old myopic children compared to emmetropic and hyperopic children (Jin et al., 2016). The interocular difference in choroidal thickness between the amblyopic eyes and the fellow eyes in our study might be related to the degree of myopia and the axial length. A difference that most apparent at perifoveal 6 mm subfield, a region closest to the optic nerve head.

Previous studies on the choroidal thickness profile in anisometropic hyperopic amblyopia (Mori et al., 2014; Nishi et al., 2014; Tenlik et al., 2014) reported different thickness profile of the choroid in their amblyopes compared with ours. The choroid of their amblyopic eyes showed different profile, namely that the choroid was thickest in the subfoveal region, followed by the temporal region and the thinnest at the nasal. Taken together previous research findings on the hyperopic anisometropic amblyopia and the results of the present study, choroidal thickness profile seemed to vary with the types of refractive amblyopia. Although our findings revealed the choroidal thinning in the myopic anisometropic amblyopia, it remained inconclusive whether the choroid of the amblyopic eye thinned in relation to the fellow eye because it failed to alter its thickness in the presence of amblyopia or as a result of higher degree of myopia progression during the eye development. A future study might benefit from a larger sample size of the amblyope, direct comparison with a control group with age-match and refractive-match with the amblyope, prospective longitudinal follow up study design. The information would be useful to establish our understanding of the potential role of the choroid during early eye development.

CONCLUSION

As the conclusion of the choroidal thickness study of children with myopic anisometropic amblyopia, the amblyopic eyes were found to have thinner choroid compared with the fellow eyes at all macular subfields. The choroidal thickness profile of the amblyopic eyes was also different from the fellow eyes.

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REFERENCES


