Macular Choroidal Thickness in Normal Pediatric Population Measured by Swept-Source Optical Coherence Tomography

José M. Ruiz-Moreno,1,2 Iñaki Flores-Moreno,1 Francisco Lugo,2 Jorge Ruiz-Medrano,2 Javier A. Montero,3 and Masahiro Akiba4

PURPOSE: To evaluate choroidal thickness in healthy pediatric population by swept-source longer-wavelength optical coherence tomography (SS-OCT).

METHODS. This was a cross-sectional comparative, noninterventional study. The macular area of 83 eyes from 43 pediatric patients (<18 years) was studied with an SS-OCT prototype system. Macular choroidal thickness was manually determined at 750-μm intervals by measuring the perpendicular distance from the posterior edge of the RPE to the choroid/sclera junction, along a horizontal 4500-μm line centered in the fovea. Three observers independently determined choroidal thickness. Pediatric choroidal thickness was compared with choroidal thickness from 75 eyes from 50 normal healthy adult volunteers (18 years or older).

RESULTS. Mean age was 10 ± 3 years (3–17) in the pediatric population versus 55 ± 16 (25–85) in the adult population (P < 0.001). Mean spherical equivalent was not different (P = 0.06) between both groups. Mean subfoveal choroidal thickness was 312.9 ± 65.3 μm in the pediatric versus 305.6 ± 102.6 μm in the adult population (P = 0.19). Mean macular choroidal thickness was 285.2 ± 56.7 μm in the pediatric versus 275.2 ± 92.7 μm in the adult population (P = 0.08). The distribution of choroidal thickness along the horizontal line was different for both populations; the temporal choroid was thicker in the pediatric population (320, 322, and 324 μm; P = 0.002, 0.001, and 0.06, respectively), followed by the subfoveal (312 μm) and nasal choroid (281, 239, and 195 μm).

CONCLUSIONS. Macular choroidal thickness in the pediatric population is not significantly thicker than that of healthy adults. Differences are more remarkable in the temporal side of the fovea. (Invest Ophthalmol Vis Sci. 2013;54:353–359) DOI: 10.1167/iovs.12-10863

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Choroidal thickness was determined under the fovea (subfoveal choroidal thickness); three further determinations were performed every 750 μm temporal (T1, T2, and T3) and nasal (N1, N2, and N3) to the fovea (Fig. 1). Average macular horizontal choroidal thickness was calculated as the average of these seven determinations.

An average macular profile was calculated as a line formed by the mean values of each point (T3, T2, T1, subfoveal, N1, N2, and N3) in the pediatric and adult groups.

Pedicatric choroidal thickness was compared with that of normal healthy adult volunteers (18 years or older). Eyes with spherical equivalent (SE) beyond ±6 diopters (D) or ocular conditions were excluded from both groups. An experienced technician determined refractive errors using an auto-refractometer (Nidek, Gamagohri, Japan) that was later checked by a certified optometrist.

Three observers determined choroidal thickness independently and the final thickness was calculated as the arithmetic mean of the...
RESULTS

The macular area of 83 eyes from 43 healthy pediatric individuals (<18 years) was studied with an SS-OCT prototype system and compared with 75 eyes from 50 normal healthy adult volunteers (18 years or older).

SS-OCT allowed visualization of choroidal thickness in all the cases (100%) in both groups (Fig. 1). Mean age in the pediatric population was 10 ± 3 years (3-17) versus 53 ± 16 years (25-85) in the adult group (P < 0.001; Student's t-test). Mean SE was similar in both groups (0.3 ± 2.0 D, range ±3.75 to −5.25 in children versus 0.16 ± 1.4 D, range ±3.25 to −5.0 in adults; P = 0.06; Student's t-test). Mean subfoveal choroidal thickness was 312.9 ± 65.3 μm (158–469) in children versus 305.6 ± 102.6 μm (152–624) in adults (P = 0.19; Mann-Whitney U test). Average macular horizontal choroidal thickness was 285.2 ± 56.7 μm (153–399) in children versus 275.2 ± 92.7 μm (132–551) in adults (P = 0.08; Mann-Whitney U test; Table 1).

Pediatric choroidal thickness was highest in the temporal side (320, 322, and 324 μm for T3, T2, and T1, respectively; confidence intervals 13.2, 12.9, and 13.0 μm, respectively); then in the fovea (312 μm; confidence interval 14.1 μm); and thinnest in the nasal side (281, 239, and 195 μm for N1, N2, and N3 respectively; confidence intervals 14.1, 13.3, and 12.5 μm, respectively). Adult choroidal thickness was highest in the fovea (305 μm; confidence interval 23.3 μm); followed by the temporal (281, 290, 299 μm for T3, T2, and T1, respectively; confidence intervals 18.5, 20.3, and 21.6 μm, respectively); and the nasal side (290, 253, 205 μm for N1, N2, and N3 respectively; confidence intervals 23.8, 23.4, and 22.5 μm, respectively; Fig. 2). Differences in choroidal thickness between both groups were statistically significant at T3 and T2 (P = 0.002 and P = 0.01, respectively; Student's t-test) and near significance in T1 (P = 0.06, Student's t-test). Differences in subfoveal and nasal choroidal thickness were not statistically significant.

The average temporal choroidal thickness within the pediatric group was lower in the group formed by children 10 to 17 years (n = 35 eyes) than among children aged 3 to 9 years (n = 48 eyes); but the differences between both groups were less marked in the nasal sectors (Fig. 2B).

Correlation between macular horizontal choroidal thickness and age or SE and between subfoveal choroidal thickness and SE in the pediatric group was r = −0.25 (P = 0.02); r = 0.37 (P = 0.001); and r = 0.41 (P = 0.000), respectively. Correlation between choroidal thickness and age in the whole population was weak or not significant at N3, N2, N1, and fovea, and significant at T1 (r = −0.22, P = 0.004); T2 (r = −0.29, P = 0.000); and T3 (r = −0.33, P = 0.000; Fig. 3).

The intraclass correlation coefficient for choroidal thickness for the three independent observers was between 0.91 and 0.98. The Bland-Altman plots showed small differences and narrow limits of agreement for choroidal thickness for interobserver comparison, suggesting satisfactory agreement between the observers. Most of the data points were tightly clustered around the zero line of the difference between the two choroidal thickness determinations and 95% to 97.5% of the determinations fell within limits of agreement (Fig. 4).

DISCUSSION

Choroidal research has always been difficult. ICGA permits visualization of choroidal vessels and recent advances in OCT technology have added cross-sectional information about the choroid. Enhanced-depth imaging provided by SD-OCT has permitted cross-sectional research of the choroid, increasing our knowledge on the pathophysiology and etiology of several ocular conditions. Long wavelength SS-OCT prototypes (1050–1060 nm) have been used in patients improving image quality. Faster and higher quality software may overcome RPE barrier effect and movement artifacts.
Papers on choroidal thickness report a progressive choroidal thinning associated with age. Margolis described 1.56-μm thinning for each year of life. Agawa and Li reported that such correlation between choroidal thickness and age did not exist in eyes with axial length < 25 mm. The effect of age on pediatric choroidal thickness has not been studied previously.

In our series, SS-OCT allowed visualization of the choroid in all the cases with high-quality images (Fig. 1), permitting choroidal thickness determination. Our data suggest that the temporal choroid may become thinner with age, even thinner than the subfoveal choroid in the adult population. This finding is reinforced by the significant inverse correlation between choroidal thickness and age in the whole group at T1, T2, and T3 (Fig. 3).

The average values of choroidal thickness in our adult group were in agreement with previously reported series with similar age distribution (Table 2). Due to the strong correlation between age and choroidal thickness in adults, the age factor should be carefully considered when comparing populations with different age distributions. Mean subfoveal choroidal thickness in our adult group (312.9 ± 65.3 μm) was compared to pediatric thickness (Table 1).

### Table 1. Patients’ Demographics and CT

<table>
<thead>
<tr>
<th></th>
<th>Pediatric Population</th>
<th>Adult Population</th>
<th>P Value</th>
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<tbody>
<tr>
<td>n (eyes)</td>
<td>83</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Mean age; y</td>
<td>9.6 ± 3.1; 3–17</td>
<td>53.2 ± 15.6; 25–85</td>
<td>P &lt; 0.001; Student’s t-test</td>
</tr>
<tr>
<td>Mean SE</td>
<td>0.3 ± 2.0 μm; 3.75 to –5.25</td>
<td>–0.16 ± 1.4 μm; 3.25 to –5.0</td>
<td>P = 0.06; Student’s t-test</td>
</tr>
<tr>
<td>Mean subfoveal CT</td>
<td>312.9 ± 65.3 μm; 158–469</td>
<td>305.6 ± 102.6 μm; 152–624</td>
<td>P = 0.19; Mann-Whitney U test</td>
</tr>
<tr>
<td>Mean macular CT</td>
<td>285.2 ± 56.7 μm; 153–399</td>
<td>275.2 ± 92.7 μm; 132–551</td>
<td>P = 0.08; Mann-Whitney U test</td>
</tr>
<tr>
<td>Subfoveal CT 95% CI</td>
<td>298.7–327.3 μm</td>
<td>281.9–329.4 μm</td>
<td></td>
</tr>
<tr>
<td>Macular CT 95% CI</td>
<td>272.9–297.8 μm</td>
<td>250.6–293.3 μm</td>
<td></td>
</tr>
<tr>
<td>Definite chorioid/sclera junction, %</td>
<td>100</td>
<td>100</td>
<td></td>
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</tbody>
</table>

CT, choroidal thickness.
FIGURE 4. Bland-Altman plots representing the differences in interobserver determinations of choroidal thickness. Solid lines represent mean difference and dashed lines show the lower and upper 95% limits of agreement. Most of the data points are tightly clustered around the zero line of the difference between the two choroidal thickness determinations.
was higher than the average values reported in other series with younger patients (Table 2).

Even though the retinal landmarks may be slightly different from those reported in the literature, most of the choroidal thickness results were very similar considering Margolis’ age-correction for choroidal thickness (1.56 μm reduction per year).28 We were unable to compare these data with those from our pediatric group since such data have not been previously reported. In our series, we have not found significant differences between adults and children except for the temporal choroid. The age at which subfoveal choroidal thickness starts to decrease, as has been suggested by some authors, is still to be determined.28 This decline is probably related to aging vascular changes. We have found a significant correlation between macular choroidal thickness and age, macular choroidal thickness, and SE and between subfoveal choroidal thickness and SE within the pediatric group.

The topographic profile of choroidal thickness in the adult group in our series (Fig. 2) was highest in the subfoveal area, followed by the temporal and nasal areas, as has been previously reported in other series.1,26–29 However, this profile followed by the temporal and the nasal areas, as has been previously reported in other series.1,26–29 However, this profile was different in the pediatric population: choroidal thickness was highest in the temporal choroid with 320, 322, and 324 μm and the subfoveal choroid with 312 μm, and the nasal choroid with 281, 239, and 195 μm (Fig. 2).

The subgroup analyses of the pediatric population showed that the profile of choroidal thickness seems to change progressively during the second decade of life, as the child grows older. These changes in choroidal thickness probably reflect vascular remodeling associated with choroidal maturational. The higher metabolic needs of the fovea compared with the surrounding retina may cause a reduction of the thickness of the temporal choroid, while sparing the subfoveal choroid.

OCT devices reported in the literature provide different qualities of imaging, permitting a more or less adequate visualization of the line delimiting the choroid and the sclera. In our series, all the patients examined by SS-OCT showed a clearly defined, measurable posterior portion of the choroid. Measurable choroidal thickness has been reported in 90% of the eyes examined by Cirrus HD-OCT and in 95.8% of the eyes examined by Heidelberg EDI-OCT.40 Two papers comparing OCT equipments reported 96.4%1 and 90.7% measurability.41 Choroidal visualization was better in those studies using longer wavelength equipments. The high intra-class correlation coefficient (0.91–0.98) and the narrow limits of agreement of the Bland-Altman plots for the three independent observers highlight SS-OCT accuracy in choroidal thickness determination.

In the present study, we have considered SE instead of axial length determinations since previous indications from the literature show that refraction, which is more convenient to obtain, provides equivalent modeling capability as axial length.42

Among the limitations of this study, we may mention that choroidal thickness has to be manually determined since there is no commercially available automated software. To our best knowledge, this is the first report of choroidal thickness determination in children using SS-OCT. A few studies have been previously performed in adults using SS-OCT26,36,38 with different age distributions.

According to our results, macular choroidal thickness is similar in the healthy pediatric and adult population with different choroidal thickness profiles. New studies about choroidal thickness in pediatric population are required to confirm our findings. Knowledge of the normal choroidal thickness and choroidal thickness profile may aid in the understanding of normal changes and the appearance of choriotinal conditions in pediatric eyes.

### References


### Table 2: Characteristics of Subfoveal CT

<table>
<thead>
<tr>
<th>Study</th>
<th>Mean Age</th>
<th>Cases</th>
<th>Subfoveal CT</th>
<th>OCT System</th>
<th>Relation Age/CT</th>
<th>Definite Choroid/Sclera Junction, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruiz-Moreno adult group</td>
<td>53.2</td>
<td>75</td>
<td>305</td>
<td>SS-OCT</td>
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<td>100</td>
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<td>Margolis26</td>
<td>50.4</td>
<td>54</td>
<td>287</td>
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<td>Cirrus</td>
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<td>Ikuno26</td>
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<td>86</td>
<td>354</td>
<td>SS-OCT</td>
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<td>100</td>
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<tr>
<td>Agawa38</td>
<td>32.9</td>
<td>43</td>
<td>348</td>
<td>SS-OCT</td>
<td>-</td>
<td>100</td>
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<tr>
<td>Li19</td>
<td>24.9</td>
<td>93</td>
<td>312</td>
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<tr>
<td>Branchini1</td>
<td>35.2</td>
<td>28</td>
<td>337 to 347</td>
<td>Cirrus Spectralis RTVue</td>
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<td>Ouyang29</td>
<td>32.8</td>
<td>59</td>
<td>297</td>
<td>Cirrus</td>
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<tr>
<td>Ruiz-Moreno pediatric population</td>
<td>9.6</td>
<td>83</td>
<td>312</td>
<td>SS-OCT</td>
<td>-/+</td>
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