

Original Research Article

Macular thickness measurement via Heidelberg Spectralis SD-OCT in pediatric patients

ABSTRACT:

Aims: To determine the normative values of the macular thickness measurements via spectral-domain optical coherence tomography (SD-OCT) in healthy pediatrics.

Study design: Prospective study.

Place and Duration of Study: Beyoglu Eye Training and Research Hospital. Department of Retina, between November 2013 and May 2014.

Methodology: Sixty eyes of 30 healthy pediatric patients (20 females, 10 males) were included in this prospective study. Macular thickness measurements were performed via Spectralis SD-OCT. The average retinal thicknesses of the nine macular sectors as defined by the Early Treatment Diabetic Retinopathy Study and central macular volume were recorded.

Results: The mean age was 10.8 ± 3.1 years (range 6 - 15). The mean central macular thickness was 261 ± 27 μm (range 223 - 434). The mean central volume was 8.66 ± 0.32 mm^3 (range 8.01 – 9.54). The mean thickness was 342 ± 13 μm for superior inner, 327 ± 15 μm for temporal inner, 341 ± 22 μm for inferior inner, 339 ± 20 μm for nasal inner, 300 ± 11 μm for superior outer, 286 ± 15 μm for temporal outer, 291 ± 11 μm inferior outer, 315 ± 23 μm for nasal outer segment.

Conclusion: The means and normative reference ranges are provided for Spectralis OCT in healthy pediatrics, between 6-15 years old, and this values can be used as a standard to compare those of children suspected of having retinal or optic nerve abnormalities.

Keywords: macular thickness, optical coherence tomography, SD-OCT, normative data

1. INTRODUCTION

Optical coherence tomography (OCT) is a noninvasive, cross-sectional and highly reproducible imaging technique that can measure macular thickness [1]. OCT rapidly has become a popular technique for diagnosing and determining progression of retinal diseases and glaucoma [2]. Macular thickness can be evaluated with slit-lamp biomicroscopic examination qualitatively. However, OCT as an automated computerized device, may measure the macular thickness quantitatively and objectively [3]. Beside of being a diagnostic tool, OCT also can be used for monitoring disease progression and the effectiveness of treatment.

The first description of OCT by Huang et al was in 1991 [4]. OCT works similar way with ultrasound systems, but it uses light waves instead of sound waves [5]. For measuring the light echoes, OCT uses a spectrometer [5]. Historically, the first systems were time-domain OCT (TD-OCT) technologies. TD-OCT devices can perform 400 A-scans per second and the axial resolution of time-domain system is 10 μm [6]. Recently, spectral-domain OCT (SD-OCT) became available and can perform over 40,000 A-scans per second with and axial resolution 4-7 μm [6]. Via its improved axial resolution and speed of SD-OCT, smaller morphologic changes became identifiable [7].

Macular thickness may be affected by many ocular and systemic diseases and normal databases are needed to distinguish normal macular thickness measurements from abnormal measurements [8]. Macular thickness measurements via OCT and their reproducibility have been studied extensively in the past [9,10]. However, a normative database is not available for pediatric patients for many devices. In this study, we aimed to define the normal values of macular OCT for Spectralis SD-OCT (Heidelberg Engineering, Inc., Vista, CA) in pediatric population.

2. MATERIAL AND METHODS

Sixty eyes of 30 patients (20 female, 10 male) were included in this prospective cross-sectional study. The inclusion criteria were: age 6 to 15 years old, best-corrected visual acuity 20/20 or better, refractive error not exceeding ± 3 diopters spherical equivalent, no ophthalmic or systemic diseases, no medical or family history of retinal diseases or glaucoma, no prior ocular surgery. Parents of all participants were volunteers and the study was performed according to the Helsinki declaration. This study was approved by the local ethics committee.

All subjects underwent a full ophthalmic examination, including OCT imaging. OCT scanning was performed via Spectralis SD-OCT. This OCT system has a resolution of 7 μm and the light source used is SLD centered at a wavelength of 870 nm. Device has eye-tracking technology recognizes the presence of eye movement then repositions the scan pattern and discards scans with motion artifacts. Also high speed scanning eliminates chances of artifacts. Fast macula protocol was used to obtain the retinal scans, with a automatic real time (ART) mean value of 9, which acquires 25 horizontal lines (6x6 mm area), each consisting of 1024 A scans per line. The CRT was defined as the distance between the ILM to the outer border of the retinal pigment epithelium via the automatic segmentation algorithms of the Spectralis software. Spectralis SD-OCT shows the results of macular thickness measurements in screen or printout. Macula is divided 9 regions, including a center circle of 500 μm radius, and inner and outer ring, each divided into four quadrants. An average retinal thickness and retinal volume are reported in numerical in central, superior inner, inferior inner, temporal inner, nasal inner, superior outer, inferior outer, temporal outer, nasal outer regions (Figure 1). The printout also shows the central volume measurement.

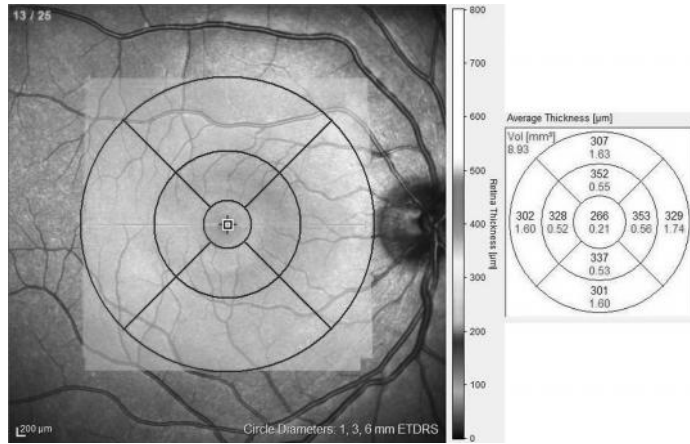


Fig. 1. The thickness analysis protocol reconstructed a false-color topographic image and also shows numeric averages of the thickness measurements for each of the nine map sectors as defined by the Early Treatment Diabetic Retinopathy Study (ETDRS). 1 mm, 3 mm and 6 mm circles are used to create 9 regions. Black numbers show macular thickness in μm and red numbers shows volume in mm^3 . Total volume of the 6 mm zone is also shown.

3. RESULTS

The mean age was 10.8 ± 3.1 years (range 6 - 15). The mean refractive error was 0.22 ± 1.75 diopter spherical equivalents. The mean central macular thickness was $261 \pm 27 \mu\text{m}$ (range 223 - 434). The mean central volume was $8.66 \pm 0.32 \text{ mm}^3$ (range 8.01 – 9.54). Table 1 shows the measurements for all quadrants (Table 1).

Table 1. Macular thickness measurements in μm .

	Mean	$\pm$ sd	Min.	Max.
Central	261	27	223	434
Superior Inner	342	13	320	384
Temporal Inner	327	15	294	380
Inferior Inner	341	22	297	473
Nasal Inner	339	20	261	417
Superior Outer	300	11	270	332
Temporal Outer	286	15	256	342
Inferior Outer	291	11	263	319
Nasal Outer	315	23	203	369

The macula was thinnest in the center 1 mm zone and thickest in the inner ring, then gradually thinned toward the outer ring. In the inner 3 mm ring, the order of macular thickness was superior>inferior>nasal>temporal. In the outer 6 mm ring, the order was nasal>superior>inferior>temporal.

4. DISCUSSION

In this study, we evaluated the healthy pediatric population to define the normal values of macular OCT for Spectralis SD-OCT. All OCT devices define the inner retinal boundary as the internal limiting membrane. They differ in defining the outer retinal boundary. TD-OCT defined the outer boundary of the retina as IS/OS hyper-reflective band [11]. Newer high resolution SD-OCT devices the outer retina can be visualized as 3 bands; the IS/OS junction, the photoreceptor OS tips and the retinal pigment epithelium (RPE).X SD-OCT measures the distance from the internal limiting membrane to RPE [12]. The previous studies showed that the distance between the IS/OS band and the retinal pigment epithelium about 34 μm at the foveal center, and it differs to 80 μm with eccentricity [11,13,14]. Kakinoki et al reported that the macula was 60- μm thicker with SD-OCT than when measured with TD-OCT [15]. Domalpally et al reported that the mean difference in central subfield thickness between the two types of instruments was $24.5 \pm 20.9 \mu\text{m}$ in 127 healthy eyes [16]. Huang et al compared retinal thickness measurements between two types of OCT devices and reported that center macular thickness measurements via SD-OCT was 7.7% thicker [11]. They also added that macular thickness measurements may vary in the same type but different manufacturer's devices.

Currently, there is no consensus in the community about which outer boundaries to use for calculation of macular thickness [14]. The IS/OS band, the inner border of RPE and the outer border of RPE may chose as outer boundary. Each has some advantages and disadvantages. The IS/OS band has the highest contrast and easy to detect in normal eyes, but using this band excludes the OS from measurements. The inner border of RPE may be chose for quantifying disease affecting inner retinal layers; however the outer border of RPE might be more beneficial in diseases involving the RPE.

A few studies have examined macular thickness measurements in pediatrics via SD-OCT instruments [18-20]. Yanni et al reported that the mean central subfield macular thickness via Spectralis in healthy pediatrics was $271.2 \pm 2.0 \mu\text{m}$ and there was no significant difference with sex or race/ethnicity [18]. However, they reported that there was a significant increase in central foveal subfield thickness with age [18]. Altemir et al reported that the mean macular thickness via Cirrus OCT was $282.91 \pm 11.83 \mu\text{m}$ in healthy pediatrics and all the parameters they evaluated were highly reproducible [19]. Turk et al reported that the average macular thickness via Spectralis in healthy pediatrics was $326.44 \pm 14.17 \mu\text{m}$ and they added that SD-OCT can be reliably used for pediatric patients because of its short exposure time and high degree of image resolution [20].

5. CONCLUSION

SD-OCT may be useful for children with glaucoma or retinal diseases and the normative reference ranges for each of the SD-OCT parameters for children enhance our ability to diagnose pediatric disorders affecting the retina. Because of the change in segmentation algorithm and effect of resolution of the images, each device need unique database. Also some studies have shown differences in macular thickness with age [19]. Spectralis OCT device does not have a normal database for pediatric patients, and there are only a few studies regarding this issue. Further studies may be needed for establishing normative databases for different refractive errors.

135

136 .

137

138 REFERENCES

139

140 [1] Liu L, Zou J, Jia L, Yang JG, Chen SR. Spectral- and time-domain optical coherence
141 tomography measurements of macular thickness in young myopic eyes. *Diagn Pathol*
142 2014;9(1):38.

143 [2]. Kim GA, Kim JH, Lee JM, Park KS. Reproducibility of peripapillary retinal nerve fiber
144 layer thickness measured by spectral domain optical coherence tomography in
145 pseudophakic eyes. *Korean J Ophthalmol* 2014;28(2):138-49.

146 [3]. Elbendary AM, Mohamed HR. Discriminating ability of spectral domain optical coherence
147 tomography in different stages of glaucoma. *Saudi J Ophthalmol* 2013;27(1):19-24.

148 [4]. Huang D, Swanson EA, Lin CP, Schuman JS, Stinson WG, Chang W, Hee MR, Flotte T,
149 Gregory K, Puliafito CA. Optical coherence tomography. *Science* 1991;254(5035):1178-81.

150 [5]. Lee KH, Kang MG, Lim H, Kim CY, Kim NR. A formula to predict spectral domain optical
151 coherence tomography (OCT) retinal nerve fiber layer measurements based on time domain
152 OCT measurements. *Korean J Ophthalmol* 2012;26(5):369-77.

153 [6]. Hunter A, Chin EK, Telander DG. Macular edema in the era of spectral-domain optical
154 coherence tomography. *Clin Ophthalmol* 2013;7:2085-89.

155 [7]. Wolf S, Wolf-Schnurrbusch U. Spectral-domain optical coherence tomography use in
156 macular diseases: a review. *Ophthalmologica* 2010;224(6):333–340.

157 [8]. Gregori G, Knighton RW, Puliafito CA, Legarreta JE, Punjabi OS, Lalwani GA. Macular
158 Thickness Measurements in Normal Eyes Using Spectral Domain Optical Coherence
159 Tomography. *Ophthalmic Surg Lasers Imaging* 2008;39(4):43-9.

160 [9]. Leung CK, Cheung CY, Winreb RN, et al. Comparison of macular thickness
161 measurements between time domain and spectral domain optical coherence tomography.
162 *Invest Ophthalmol Vis Sci* 2008;49:4893– 4897.

163 [10]. Forooghian F, Cukras C, Meyerle CB, Chew EY, Wong WT. Evaluation of time domain
164 and spectral domain optical coherence tomography in the measurement of diabetic macular
165 edema. *Invest Ophthalmol Vis Sci* 2008;49:4290–4296.

166 [11]. Huang I, Liu X, Wu Z, Xiao H, Dustin L, Sadda S. Macular Thickness measurements in
167 normal eyes with time-domain and fourier-domain optical coherence tomography. *Retina*
168 2009;29:980–987.

169 [12]. Srinivasan VJ, Wojtkowski M, Witkin AJ, et al. High-definition and 3-dimensional
170 imaging of macular pathologies with high-speed ultrahigh-resolution optical coherence
171 tomography. *Ophthalmology* 2006;113:2054.

172 [13]. Sadda SR, Joeres S, Wu Z, et al. Error correction and quantitative subanalysis of
173 optical coherence tomography data using computer-assisted grading. *Invest Ophthalmol Vis*
174 *Sci* 2007; 48:839–848.

- 175 [14]. Sull AC, Vuong LN, Price LL, Srinivasan VJ, Gorczynska I, Fujimoto JG, Schuman JS,
176 Duker JS. Comparison of spectral/Fourier domain optical coherence tomography
177 instruments for assessment of normal macular thickness. *Retina*. 2010 Feb;30(2):235-45.
- 178 [15]. Kakinoki M, Sawada O, Sawada T, Kawamura H, Ohji M. Comparison of macular
179 thickness between Cirrus HD-OCT and Stratus OCT. *Ophthalmic Surg Lasers Imaging*
180 2009;40(2):135-40.
- 181 [16]. Domalpally A, Gangaputra S, Peng Q, Danis RP. Repeatability of retinal thickness
182 measurements between spectral-domain and time-domain optical coherence tomography
183 images in macular disease. *Ophthalmic Surg Lasers Imaging* 2010;41:34-41.
- 184 [17]. Alamouti B, Funk J. Retinal thickness decreases with age: an OCT study. *Br J*
185 *Ophthalmol* 2003;87:899 –901.
- 186 [18]. Yanni SE, Wang J, Cheng CS, Locke KI, Wen Y, Birch DG, Birch EE. Normative
187 reference ranges for the retinal nerve fiber layer, macula, and retinal layer thicknesses in
188 children. *Am J Ophthalmol* 2013;155(2):354-360.
- 189 [19]. Altemir I, Pueyo V, Elía N, Polo V, Larrosa JM, Oros D. Reproducibility of optical
190 coherence tomography measurements in children. *Am J Ophthalmol* 2013;155(1):171-76.
- 191 [20]. Turk A, Ceylan OM, Arici C, Keskin S, Erdurman C, Durukan AH, Mutlu FM, Altinsoy HI.
192 Evaluation of the nerve fiber layer and macula in the eyes of healthy children using spectral-
193 domain optical coherence tomography. *Am J Ophthalmol* 2012;153(3):552-59.
- 194