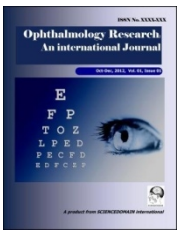

Ophthalmology Research: An International Journal
2(6): 384-390, 2014, Article no. OR.2014.6.013

SCIENCEDOMAIN *international*
www.sciencedomain.org

Macular Thickness Measurement via Heidelberg Spectralis SD-OCT in Pediatric Patients

Ihsan Yilmaz[1*], Abdullah Ozkaya[1], Yalcin Karakucuk[1], Irfan Perente[1] and Ahmet Taylan Yazici[1]

[1]Retina Department, Beyoglu Eye Training and Research Hospital, Istanbul, Turkey.

Authors' contributions

This work was carried out in collaboration between all authors. Author IY designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author AO managed the literature searches, analyses of the study performed the spectroscopy analysis and authors YK, IP managed the experimental process and author ATY identified the species of plant. All authors read and approved the final manuscript.

Original Research Article

Received 2nd June 2014
Accepted 3rd July 2014
Published 20th July 2014

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±27µm (range 223-434). The mean central volume was 8.66±0.32mm^3 (range 8.01-9.54). The mean thickness was 342±13µm for superior inner, 327±15µm for temporal inner, 341±22µm for inferior inner, 339±20µm for nasal inner, 300±11µm for superior outer, 286±15µm for temporal outer, 291±11µm inferior outer, 315±23µm for nasal outer segment.
Conclusion: The means and normative reference ranges are provided for Spectralis

**Corresponding author: E-mail: ihsanyilmaz.dr@gmail.com;*

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. [4] was in 1991. 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 10μm [6]. Recently, spectral-domain OCT (SD-OCT) became available and can perform over 40,000 A-scans per second with and axial resolution 4-7μm [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. MATERIALS 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 ±3diopters 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 were Middle Eastern and they were born at term.

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 87nm. 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 (6x6mm area), each consisting of 1024 A scans per line. Software ver. 4.0.0.0 was used. The central retinal thickness (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 500µm 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 (Fig. 1). The printout also shows the central volume measurement.

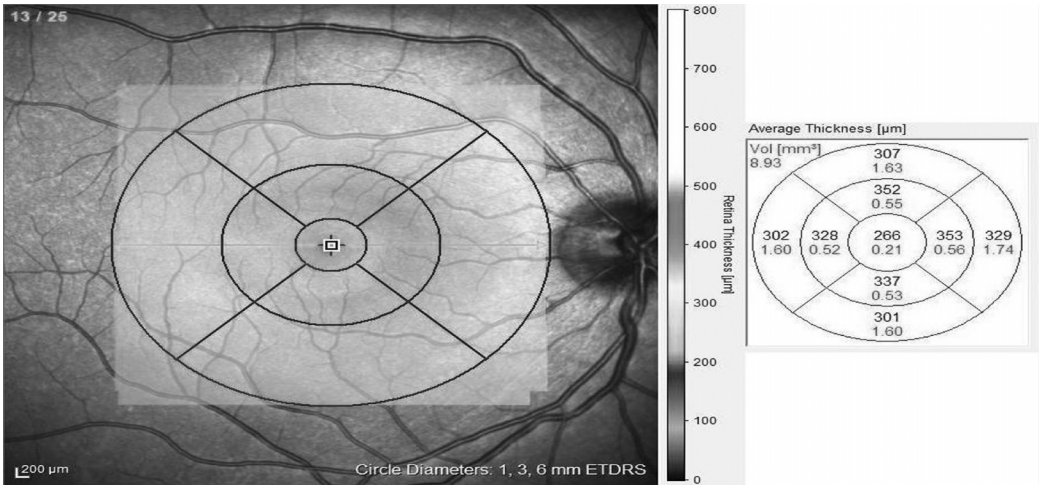

Fig. 1. The thickness analysis protocol reconstructed a false-color topographic image and also shows numeric averages of the thickness measurements for each of the nine map sectors as defined by the Early Treatment Diabetic Retinopathy Study (ETDRS). 1 mm, 3 mm and 6 mm circles are used to create 9 regions. 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±3.1years (range 6-15). The mean refractive error was 0.22±1.75 diopter spherical equivalents. The mean central macular thickness was 261±27µm (range 223-434). The mean central volume was 8.66±0.32mm^3 (range 8.01–9.54). Table 1 shows the measurements for all quadrants (Table 1).

Table 1. Macular thickness measurements in µm

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

4. DISCUSSION

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]. In 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). 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 is 34µm at the foveal center, and it differs to 80µm with eccentricity [11,13,14]. Kakinoki et al. [15] reported that the macula was 60-µm thicker with SD-OCT than when measured with TD-OCT. Domalpally et al. [16] reported that the mean difference in central subfield thickness between the two types of instruments was 24.5±20.9µm in 127 healthy eyes. Huang et al. [11] compared retinal thickness measurements between two types of OCT devices and reported that central macular thickness measurements via SD-OCT was 7.7% thicker. 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 [14,17]. 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. [18] reported that the mean central subfield macular thickness via Spectralis in healthy pediatrics was 271.2±2.0µm and there was no significant difference with sex or race/ethnicity. However, they reported that there was a significant increase in central foveal subfield thickness with age [18]. Altemir et al. [19] reported that the mean macular thickness via Cirrus OCT was 282.91±11.83µm in healthy pediatrics and all the parameters they evaluated were highly reproducible. Turk et al. [20] reported that the average macular thickness via Spectralis in healthy pediatrics was 326.44±14.17µm 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. Recently, Al-Haddad et al. [21] reported pediatric macular thickness measurements via Cirrus OCT and in their study the average macular thickness was 279.6+/-12.5μm and the central macular thickness was 249.1+/-20.2 μm, and the mean macular volume was 10.1+/-0.5mm^3. Barrio-Barrio et al. [22] present a similar study with Cirrus OCT and they reported that the average thickness was 283.62±14.08μm and the mean central macular thickness was 253.85±19.76μm.

Some limitations of this study are the small number of participants and the fact that the axial length was not measured. Also we used both eyes of each child and it may be more valid to use one eye of each participant.

5. CONCLUSION

SD-OCT may be useful for children with glaucoma or retinal diseases and the normative reference range 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 needs 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.

CONSENT

A waiver of informed consent was obtained given that this study posed less than minimal risk to all participants and did not affect patient welfare.

ETHICAL APPROVAL

All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Liu L, Zou J, Jia L, Yang JG, Chen SR. Spectral- and time-domain optical coherence tomography measurements of macular thickness in young myopic eyes. Diagn. Pathol. 2014;9(1):38.
2. Kim GA, Kim JH, Lee JM, Park KS. Reproducibility of peripapillary retinal nerve fiber layer thickness measured by spectral domain optical coherence tomography in pseudophakic eyes. Korean J Ophthalmol. 2014;28(2):138-49.
3. Elbendary AM, Mohamed HR. Discriminating ability of spectral domain optical coherence tomography in different stages of glaucoma. Saudi J Ophthalmol. 2013;27(1):19-24.

4. Huang D, Swanson EA, Lin CP, Schuman JS, Stinson WG, Chang W, Hee MR, Flotte T, Gregory K, Puliafito CA. Optical coherence tomography. Science. 1991;254(5035):1178-81.
5. Lee KH, Kang MG, Lim H, Kim CY, Kim NR. A formula to predict spectral domain optical coherence tomography (OCT) retinal nerve fiber layer measurements based on time domain OCT measurements. Korean J Ophthalmol. 2012;26(5):369-77.
6. Hunter A, Chin EK, Telander DG. Macular edema in the era of spectral-domain optical coherence tomography. Clin Ophthalmol. 2013;7:2085-89.
7. Wolf S, Wolf-Schnurrbusch U. Spectral-domain optical coherence tomography use in macular diseases: A review. Ophthalmologica. 2010;224(6):333–340.
8. Gregori G, Knighton RW, Puliafito CA, Legarreta JE, Punjabi OS, Lalwani GA. Macular thickness measurements in normal eyes using spectral domain optical coherence tomography. Ophthalmic Surg Lasers Imaging. 2008;39(4):43-9.
9. Leung CK, Cheung CY, Winreb RN, et al. Comparison of macular thickness measurements between time domain and spectral domain optical coherence tomography. Invest Ophthalmol Vis Sci. 2008;49:4893–4897.
10. Forooghian F, Cukras C, Meyerle CB, Chew EY, Wong WT. Evaluation of time domain and spectral domain optical coherence tomography in the measurement of diabetic macular edema. Invest Ophthalmol Vis Sci. 2008;49:4290–4296.
11. Huang I, Liu X, Wu Z, Xiao H, Dustin L, Sadda S. Macular thickness measurements in normal eyes with time-domain and fourier-domain optical coherence tomography. Retina. 2009;29:980–987.
12. Srinivasan VJ, Wojtkowski M, Witkin AJ, et al. High-definition and 3-dimensional imaging of macular pathologies with high-speed ultrahigh-resolution optical coherence tomography. Ophthalmology. 2006;113:2054.
13. Sadda SR, Joeres S, Wu Z, et al. Error correction and quantitative subanalysis of optical coherence tomography data using computer-assisted grading. Invest Ophthalmol Vis Sci. 2007;48:839–848.
14. Sull AC, Vuong LN, Price LL, Srinivasan VJ, Gorczynska I, Fujimoto JG, Schuman JS, Duker JS. Comparison of spectral/Fourier domain optical coherence tomography instruments for assessment of normal macular thickness. Retina. 2010;30(2):235-45.
15. Kakinoki M, Sawada O, Sawada T, Kawamura H, Ohji M. Comparison of macular thickness between Cirrus HD-OCT and Stratus OCT. Ophthalmic Surg Lasers Imaging. 2009;40(2):135-40.
16. Domalpally A, Gangaputra S, Peng Q, Danis RP. Repeatability of retinal thickness measurements between spectral-domain and time-domain optical coherence tomography images in macular disease. Ophthalmic Surg Lasers Imaging. 2010;41:34-41.
17. Alamouti B, Funk J. Retinal thickness decreases with age: an OCT study. Br J Ophthalmol 2003;87:899–901.
18. Yanni SE, Wang J, Cheng CS, Locke KI, Wen Y, Birch DG, Birch EE. Normative reference ranges for the retinal nerve fiber layer, macula, and retinal layer thicknesses in children. Am J Ophthalmol 2013;155(2):354-360.
19. Altemir I, Pueyo V, Elía N, Polo V, Larrosa JM, Oros D. Reproducibility of optical coherence tomography measurements in children. Am J Ophthalmol. 2013;155(1):171-76.
20. Turk A, Ceylan OM, Arici C, Keskin S, Erdurman C, Durukan AH, Mutlu FM, Altinsoy HI. Evaluation of the nerve fiber layer and macula in the eyes of healthy children using spectral-domain optical coherence tomography. Am J Ophthalmol. 2012;153(3):552-59.

21. Al-Haddad C, Barikian A, Jaroudi M, Massoud V, Tamim H, Noureddin B. Spectral domain optical coherence tomography in children: Normative data and biometric correlations. BMC Ophthalmol. 2014;22:14(1):53.
22. Barrio-Barrio J, Noval S, Galdós M, Ruiz-Canela M, Bonet E, Capote M, Lopez M. Multicenter Spanish study of spectral-domain optical coherence tomography in normal children. Acta Ophthalmol. 2013;91(1):e56-63. doi: 10.1111/j.1755-3768.2012.02562.

© 2014 Yilmaz et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/3.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=523&id=23&aid=5403