Original Article

Comparison of accuracy of Cirrus HD and Spectralis in analyzing optic nerve head

Quan Nhu Nguyen MD[1], Bao Hong Tran MD[2]

[1]Vice head, Vitreoretinal Department, Ho Chi Minh city Eye Hospital, Vietnam
[2]Department of Ophthalmology, Faculty of Medicine, Vietnam National University – Ho Chi Minh City, Vietnam

Abstract

Background: *Nowadays, in large eye centers, two Fourier-domain optical coherence tomography (OCT) devices are often used in parallel to obtain optical coherence tomograph images of patients, especially retinal nerve fiber layer (RNFL) thickness analysis and central retinal image. Determining system stability and accuracy, as well as finding a correlation and a formula to unify measurement values of these 2 systems are essential to finding consensus in clinical practice.*

Objectives: *To evaluate measurement errors of Cirrus HD and Spectralis OCT system in analyzing optic nerve head and the correlation of the results from these two systems.*

Methods: *Cross-sectional study. Seventy-one eyes from 38 patients underwent RNFL thickness analysis by Cirrus HD system 3 times consecutively, which was repeated after 5 minutes rest. The whole procedure was then repeated using Spectralis system, after another period of 30 minutes rest. Measurement errors of each quadrant (superior, inferior, nasal and temporal) and the overall errors were analyzed. The correlation between measurement values of Cirrus HD and Spectralis system, as well as a formula to convert Spectralis measurement values into Cirrus HD values, was conducted.*

Results: *The overall measurement error of Spectralis system was significantly higher than that of Cirrus HD system ($p=0.015$). The measurement errors of Spectralis system were also significantly higher than those of HD system in inferior, nasal and temporal zone ($p<0.05$). In both systems, the measurement errors before and after 5 minutes rest did not differ significantly ($p>0.05$). There was a strong linear correlation between Spectralis and Cirrus HD measurement values ($R=0.91$, $p<0.001$).*

Conclusion: *Spectralis system has statistically higher measurement errors than Cirrus HD system, however the difference is less likely to have clinical meaning. Both systems could be used in parallel in clinical practice with acceptable consensus.*

Keywords: *Cirrus, correlation, optical coherence tomography, reliability, retinal nerve fiber layer thickness, spectral-domain, Spectralis, stability.*

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Introduction

For ophthalmologists to manage chronic glaucoma, retinal nerve fiber layer (RNFL) thickness taken by optical coherence tomography (OCT) has been an irreplaceable mean for objectively and quantitatively monitoring glaucomatous damage.[1,2] As visual field defect is often not detected until 40% of RNFL is lost, OCT provides earlier detection of glaucomatous damage.[3] Former time-domain OCT (TD-OCT) has been demonstrated to be a reliable device to assist the clinical diagnosis and management of glaucoma.[4-6] With the development of technology, the recent spectral-domain OCT (SD-OCT) has brought out a big advantage in image resolution and software capabilities. SD-OCT improves image acquisition speed, which allows multiple parallel B-scans to be acquired and summed into 3 -dimensional (3 D) volume data sets. Depending on device used, scanning speed can vary from 29000 to 55000 A-scans/second.[7,8] This fast scanning speed results in in-tissue axial resolution from 5-7 µm, even up to 2 µm in most recent models, which is comparable to histopathological sample.[7] Various models have been available on the market: Spectralis (Heidelberg Engineering, Heidelberg, Germany), Cirrus (Carl Zeiss Meditec, Dublin, California, USA), RTVue (Optovue, Inc, Fremont, California USA).

In large eye centers, equipment of various OCT systems has become more commonly available. Moreover, a disagreement in device equipment between private clinics and large eye centers is common. In our country, as a result of organizational scale, private clinics are usually equipped with multimodal image obtaining devices (such as Spectralis), while large devices like Cirrus are often present in large eye centers. Knowledge about the reliability and stability of these OCT systems, in addition to communicating the results from these systems is essential to preventing patients from taking various unnecessary images. The aim of this study is to compare the measurement errors of Cirrus HD and Spectralis system (which are available at the same time in our eye center), as well as evaluating the correlation between measurement values of these 2 systems.

Methods

Our study was a cross-sectional study which has taken place at Ho Chi Minh city Eye Hospital. The institutional review board approved this study, and all participants gave informed consent. Male or female patients who were 18 years old or above, having eye checks at Ho Chi Minh city Eye Hospital and willing to participate were recruited in our study. Exclusion criteria were opacities of cornea, aqueous humor, lens or vitreous humor, inappropriate OCT signal strength (<6/10 on Cirrus HD and <16 dB on Spectralis) and patient's health problem which cannot spend enough time taking all OCT images.

After recording patient's age, sex, and thorough explanation, each patient underwent complete ophthalmic examination, including history, best-corrected visual acuity testing, intraocular pressure check with Goldmann applanation tonometer and slit-lamp biomicroscopy check. All the patients were dilated with Tropicamide 0.5% (Mydrins-P®, Santen®) to prepare for fundus examinations and to ensure obtained images were the best quality possible. The patients also had OCT images taken by a single experienced operator, with both OCT systems, on the same day.

After the patient's eyes were fully dilated, they had OCT images taken 3 consecutive times with Cirrus HD. After that, the patients had 5 minutes rest, and 3 consecutive images of RNFL thickness with Cirrus HD were taken again. After another period of 30 minutes rest to prevent the patients from over fatigue, the above procedure was repeated using

Spectralis system. Thickness values of 4 quadrants (superior, inferior, nasal and temporal) from all 6 images of both Cirrus HD and Spectralis were recorded.

Cirrus HD images were obtained using Optic Disc Cube 200 x 200 protocol. Under this protocol, a 3D cube of data is generated over a 6-mm-square grid of 200 horizontal scan lines, each composed of 200 A-scans. Cirrus software automatically detects the center of the optic disc and places a 3.46-mm-diameter circle over this center. From the 256 A-scans along this circle, the border of the RNFL is identified and RNFL thickness was calculated at each point along the circle. All scans are reviewed to ensure signal strength > 6.

Spectralis OCT system uses confocal scanning laser ophthalmoscope which enables real-time 3D tracking of eye movements, basing on a previously generated retinal map (TruTrack Active Eye Tracking system). This tracking feature also allows the utilization of AutoRescan feature, which helps obtain images at the exact location as previous visit(s). Spectralis system allows multiple B-scans to be acquired at an identical location on the retina, thus reducing speckle noise. The operator manually centers a 3.4-mm-diameter circle on the optic disc. TruTrack and AutoRescan feature were activated in every scan to ensure the scan circle to be fixed on the exact location. The images were obtained at the scan circle under high-resolution settings (1536 A-scans) and averaged automatically by the software. RNFL boundaries were also delineated and calculated automatically underneath the scan circle. All images were reviewed to ensure signal strength >16 dB.

Mean overall measurement error, as well as mean measurement error of each quadrant (superior, inferior, nasal and temporal) from Cirrus HD and Spectralis system were calculated to compare the accuracy of these 2 systems. Mean overall measurement error, as well as mean measurement error of each quadrant before and after 30 minutes rest of each OCT system, was calculated to rule out system stability. A regression model was then constructed to discover the correlation between measurement values of the 2 systems and to convert Spectralis measurement values into Cirrus HD measurement values, if such correlation is available.

Paired-sample t-test was used to compare measurement errors and Spearman's correlation test was used to construct a regression model. All the tests were performed by SPSS 16.0 for Windows. For all statistical tests, $p > 0.05$ was considered statistically significant.

Results

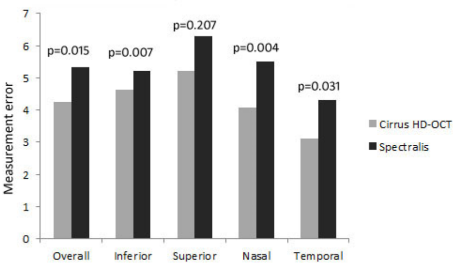
From April 2016 to October 2016, Seventy-one eyes from 38 patients were enrolled in this study. Among the patients, 33 have OCT images of both eyes taken, the other 5 have OCT images taken in only one eye due to severe cataract in the remaining eye. The baseline characteristics of our sample were shown in Table 1, and there were no statistically significant differences between sub-groups, except that most of patients are from 41 to 60 years old.

Table 1. Baseline characteristics

Variable	N	Percentage
Age (mean±SD)	46.9±12.7	
Age group		
18-40	10	26.3
41-60	23	60.5
>60	5	13.2
Gender		
Male	18	47.4
Female	20	52.6
Eye		
OD	37	52.1
OS	34	47.9

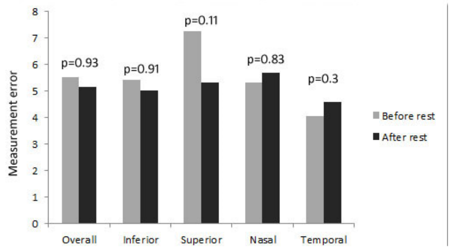
Comparison between Cirrus HD and Spectralis measurement errors was demonstrated in Figure 1. Mean overall measurement error was 4.26±3.38µm with Cirrus HD and 5.33±5.25µm with Spectralis, this difference was statistically significant (p=0.015). Mean inferior quadrant measurement error was 4.62±3.64µm with Cirrus HD and 5.22±6.71µm with Spectralis, this difference was statistically significant (p=0.007). Mean superior measurement error was 5.21±5.77µm with Cirrus HD and 6.29±8.42µm with Spectralis, this difference was not statistically significant (p=0.207). Mean nasal quadrant measurement error was 4.07±4.41µm with Cirrus HD and 5.51±6.21µm with Spectralis, this difference was statistically significant (p=0.004). Mean temporal quadrant measurement error was 3.12±4.58µm with Cirrus HD and 4.32±4.69µm with Spectralis, this difference was statistically significant (p=0.031).

Figure 1. Measurement error comparison between Cirrus HD and Spectralis



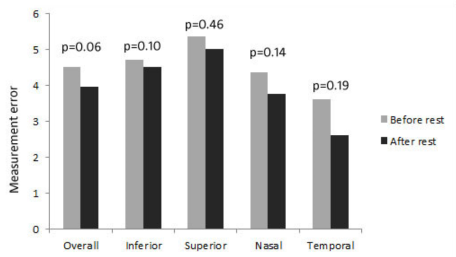
Comparison between measurement errors of Spectralis system before and after 5 minutes rest was shown in Figure 2. Measurement errors before and after 5 minutes rest were, in order, 5.52±5µm and 5.15±5.52µm overall (p=0.93), 5.42±6.68µm and 5.02±6.78µm in inferior quadrant (p=0.91), 7.25±9.92µm and 5.33±6.52µm in superior quadrant (p=0.11), 5.34±5.85µm and 5.68±6.59µm in nasal quadrant (p=0.83) and finally, 4.05±3.94µm and 4.59±5.36µm in temporal quadrant (p=0.30). Except the nasal quadrant, all the differences were not statistically significant.

Figure 2. Spectralis measurement errors before and after 5 minutes rest



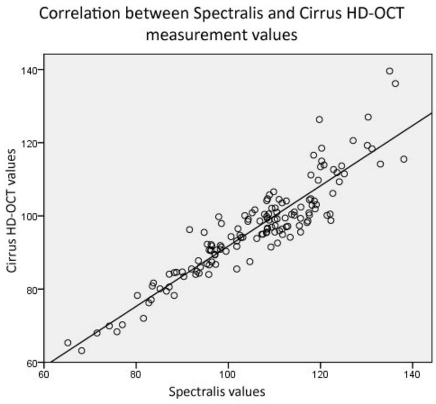
Comparison between measurement errors of Cirrus HD system before and after 5 minutes rest was shown in Figure 3. Measurement errors before and after 5 minutes rest were, in order, 4.53±4.21µm and 3.98±2.25µm overall (p=0.06), 4.73±4.29µm and 4.51±2.88µm in inferior quadrant (p=0.10), 5.38±6.63µm and 5.03±4.79µm in superior quadrant (p=0.46), 4.38±5.04µm and 3.77±3.69µm in nasal quadrant (p=0.14) and finally, 3.62±5.96µm and 2.62±2.49µm in temporal quadrant (p=0.19). All the differences were not statistically significant.

Figure 3. Cirrus HD measurement errors before and after 5 minutes rest



As demonstrated in Figure 4, Spectralis measurement values were found to be tightly correlated with Cirrus HD measurement values in linear manner (Spearman's correlation coefficient=0.91, p<0.001). Using the following formula, Spectralis measurement values (S-value) can be converted into Cirrus HD measurement values (C-value): *C-value = 0.82 x S-value + 9.4*

Figure 4. Correlation between Spectralis and Cirrus HD measurement values



Discussion

Since its emergence, SD- OCT has demonstrated its advantage when compared to TD- OCT with higher image resolution and has been used more frequently both in clinical practice and in studies, whether they are ongoing, planned or longitudinal in nature.[9-12] Various commercial SD-OCT systems are available on the market. However, in private clinic, multimodal imaging system like Spectralis is preferred as it is compact and versatile, which can take near- infrared, fundus autofluorescence, red free, fluorescein angiography and indocyanine green angiography image using just one platform. While in large eye centers, a larger system like Cirrus is often used. On the other hand, various SD- OCT systems may be used conjunctively in large eye centers. A communication between the results of different systems – Spectralis and Cirrus in our case – is essential. Hence, we compare two systems of SD-OCT in a head-to-head study of normal patients. In our knowledge, this is the only study comparing directly measurement errors of two SD-OCT systems, as well as the only one finding a direct correlation between two SD-OCT systems. As there is a difference between actual histopathological thickness and image scan thickness of RNFL[13], we did not mention RNFL thickness and only focused on absolute measurement errors, instead of relative errors.

As demonstrated in Figure 1, Spectralis between-scan measurement errors seem to be significantly larger than those of Cirrus HD, except the superior quadrant. Both Spectralis and Cirrus HD had between-scan measurement errors >3 μm. Compared to proposed measurement errors manufacturers, the high measurement errors in our study is reasonable as we set the study environment close to clinical practice as much as possible, and this is a keen proof that clinical practice is always far more complicated than research environment. In the author's opinion, there are several reasons to explain the measurement errors the difference between the two systems. First, the software algorithms of Spectralis and Cirrus HD are different; one of which is that the scan circle diameter is 3.46 mm in Cirrus HD and 3.4mm in Spectralis. The smaller circle results in thicker RNFL, and hence higher measurement errors. However, we cannot explain more clearly as we do not have much information about how the different software was coded. Second, the operator's knowledge, skill and experience takes an important role, especially when the operator has to manually place the scan circle on the optic disc center with Spectralis system. The operator may be more used to Cirrus HD than the newly available Spectralis in our eye center. Third, the patient's cooperation can contribute to measurement errors; therefore, patient's explanation and mental preparation are essential. Finally, many other factors may affect the concentration of both the patients and the operator, such as room temperature, light exposure and noise exposure. The authors believe that insignificant difference in measurement error of superior quadrant is just a coincidence.

Figure 2 and 3 demonstrated that the differences in between- visit measurement errors of Spectralis and Cirrus HD are insignificant, comparing to each other. These results proved that the stability of Spectralis and Cirrus HD in obtaining images of the patients on follow-up visits is comparable. However, both Cirrus HD and Spectralis had between-visit measurement errors >3 µm. The possible reasons had been mentioned before, and these measurement errors may affect the ophthalmologist's decision on clinical practice.

We also found a tight linear correlation between Spectralis and Cirrus HD measurement values, as demonstrated in the scatter plot (Figure 4). This is a proof that Spectralis and Cirrus HD measurement values are interchangeable. Using the formula above, Spectralis measurement values can be converted into Cirrus HD value with acceptable reliability, and vice versa. This finding is useful in clinical practice when the patients obtained Cirrus HD scans in one visit and then Spectralis in another visit. Therefore, it helps gain the consensus between SD- OCT systems, save the patient's time and economy burden taking unnecessary scans.

Many authors compared measurement values and announced the correlation between SD-OCT and TD-OCT before.[14-17] In a recent study, Ha, Lee and Kim compared SD- OCT and swept source OCT and concluded that the correlation between the two systems are stable.[18] Hence, the heritability of SD-OCT from past models and to future model is relatively reliable. No author has directly compared the two SD-OCT systems yet.

Our study has its limitations. First, our sample size is relatively small and does not include glaucoma patients, a study with large sample size is necessary to aid our results. The reliability and correlation of SD-OCT systems may be altered with lower RNFL thickness[19]. The study on normal eyes may help building baseline data on reliability and agreement between SD- OCT systems, which can assist in future study involving glaucoma eyes. Second, ethnical characteristics that may alter measurement results were not modified in our study.[20,21] Third, signal strength, the factor affecting directly RNFL thickness result, was not modified in our study also, as we do not have baseline data[22]. Moreover, as we focused on find measurement errors and correlation between SD- OCT systems, sensitivity and specificity of the results in management of glaucoma was not mentioned in this study. More large-scale studies with appropriate sample size, confounders modified and looking forward to find sensitivity and specificity of SD-OCT in diagnosis and monitoring of glaucoma are therefore necessary.

Conclusion

As we have discussed above, it was shown that in RNFL thickness analysis, measurement errors of Spectralis system are statistically higher than those of Cirrus HD system. However, the absolute difference is within 2 µm, which is less likely to have clinical value. The performance of both Cirrus HD and Spectralis through different visits is quite stable, which makes the previous results reliable references for the present results. It was demonstrated that there is a tight linear correlation between measurement values of Cirrus HD system and Spectralis system, which was expressed in the formula above. As different results taken by different systems after visits can be converted into unified values, the authors believe that this discovery will bring out more consensuses between ophthalmologists of different centers, as well as ophthalmologists in big eye centers that utilize both Cirrus HD and Spectralis. Patient's effort and economy can be saved, as a consequence.

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Conflict of interest

No potential conflict of interest relevant to this article was reported

References

1. Bowd C, Zangwill LM, Berry CC, et al. Detecting early glaucoma by assessment of retinal nerve fiber layer thickness and visual function. Invest Ophthalmol Vis Sci. 2001;42: 1993–2003.
2. Schuman JS. Spectral domain optical coherence tomography for glaucoma (an AOS thesis) . Trans Am Ophthalmol Soc 2008;106:426–458.
3. Quigley HA, Katz J, Derick RJ, et al. An evaluation of optic disc and nerve fiber layer examinations in monitoring progression of early glaucoma damage. Ophthalmology. 1992;99:19–28.
4. Budenz DL, Chang RT, Huang X, Knighton RW, Tielsch JM. Reproducibility of retinal nerve fiber thickness measurements using the stratus OCT in normal and glaucomatous eyes. Invest Ophthalmol Vis Sci 2005;46(7): 2440–2443.
5. Budenz DL, Fredette MJ, Feuer WJ, Anderson DR. Reproducibility of peripapillary retinal nerve fiber thickness measurements with stratus OCT in glaucomatous eyes. Ophthalmology 2008;115(4) : 661–666 e4.
6. Schuman JS, Pedut- Kloizman T, Hertzmark E, et al. Reproducibility of nerve fiber layer thickness measurements using optical coherence tomography. Ophthalmology 1996;103(11):1889–1898.
7. Chen TC, Zeng A, Sun W, Mujat M, de Boer JF. Spectral domain optical coherence tomography and glaucoma. Int Ophthalmol Clin 2008;48(4):29–45.
8. Mumcuoglu T, Wollstein G, Wojtkowski M, et al. Improved visualization of glaucomatous retinal damage using highspeed ultrahigh resolution optical coherence tomography. Ophthalmology 2008;115(5) : 782–789 e2.
9. Bowd C, Weinreb RN, Williams JM, Zangwill LM. The retinal nerve fiber layer thickness in ocular hypertensive, normal, and glaucomatous eyes with optical coherence tomography. Arch Ophthalmol 2000;118:22-6.
10. Williams ZY, Schuman JS, Gamell L, et al. Optical coherence tomography measurement of nerve fiber layer thickness and the likelihood of a visual field defect. Am J Ophthalmol 2002;134:538-46.
11. Chen TC, Cense B, Pierce MC, et al. Spectral domain optical coherence tomography: ultra- high speed, ultra-high resolution ophthalmic imaging. Arch Ophthalmol 2005;123:1715-20.
12. de Boer JF, Cense B, Park BH, et al. Improved signal- to- noise ratio in spectral-domain compared with time-domain optical coherence tomography. Opt Lett 2003;28:2067-9.
13. Blumenthal EZ, Parikh RS, Pe'er J, et al. Retinal nerve fibre layer imaging compared with histological measurements in a human eye. Eye (Lond) 2009;23:171-5.
14. Knight OJ, Chang RT, Feuer WJ, Budenz DL. Comparison of retinal nerve fiber layer measurements using time domain and spectral domain optical coherent tomography. Ophthalmology 2009;116:1271-7

15. Sung KR, Kim DY, Park SB, Kook MS. Comparison of retinal nerve fiber layer thickness measured by Cirrus HD and Stratus optical coherence tomography. Ophthalmology 2009;116:1264-70, 1270.e1.
16. Han IC, Jaffe GJ. Comparison of spectral- and time-domain optical coherence tomography for retinal thickness measurements in healthy and diseased eyes. Am J Ophthalmol 2009; 147:847-58, 858.e1.
17. Shin HJ, Cho BJ. Comparison of retinal nerve fiber layer thickness between Stratus and Spectralis OCT. Korean J Ophthalmol 2011;25:166-73.
18. Ha, Ahnul, et al. "Retinal Nerve Fiber Layer Thickness Measurement Comparison Using Spectral Domain and Swept Source Optical Coherence Tomography." Korean Journal of Ophthalmology 30.2 2016: 140-147.
19. Schuman JS, Hee MR, Puliafito CA, et al. Quantification of nerve fiber layer thickness in normal and glaucomatous eyes using optical coherence tomography. Arch Ophthalmol 1995;113:586-96.
20. Gyatsho J, Kaushik S, Gupta A, et al. Retinal nerve fiber layer thickness in normal, ocular hypertensive, and glaucomatous Indian eyes: an optical coherence tomography study. J Glaucoma 2008;17:122-7.
21. Wu Z, Vazeen M, Varma R, et al. Factors associated with variability in retinal nerve fiber layer thickness measurements obtained by optical coherence tomography. Ophthalmology 2007;114:1505-12.
22. Cheung CY, Leung CK, Lin D, et al. Relationship between retinal nerve fiber layer measurement and signal strength in optical coherence tomography. Ophthalmology 2008;115:1347-51, 1351.e1-2.