

Volume Averaging of Spectral-Domain Optical Coherence Tomography Impacts Retinal Segmentation in Children

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Introduction

- Spectral-Domain Optical Coherence Tomography (SD-OCT) improves resolution of all retinal layers and reduces image artifacts using eye tracking technology, allowing for automated segmentation and quantitative measurement of discrete retinal layers.¹⁻⁵
- SD-OCT measurements of retinal layer thicknesses have been proposed as a potential structural marker of vision in children with optic neuropathy.⁶⁻¹²
- Despite advances in SD-OCT, it remains challenging to acquire images of sufficient quality necessary for macular segmentation when imaging children.
- Other investigations have acquired measures of total retinal thickness from SD-OCT performed in children¹³⁻¹⁵ but multilayer retinal segmentation across an entire macular volume has not been reported.
- We investigated how volume averaging influenced the frequency and magnitude of automated multilayer segmentation errors from macular SD-OCT scans performed in children.

Methods

- Macular SD-OCT images were acquired with the Spectralis SD-OCT (Heidelberg Engineering) using three different volume settings (i.e., ART 1, 3, and 9 volumes) in children enrolled in a prospective OCT study.
- Total retinal, retinal nerve fiber layer, ganglion cell layer, inner plexiform layer, inner nuclear layer, and outer plexiform layer thicknesses were measured around an ETDRS grid using beta version automated segmentation software.
- The magnitude of manual segmentation required to correct the automated segmentation was classified as either minor (less than 12 lines adjusted), moderate (>12 and <25 lines adjusted), severe (>26 and < 48 lines adjusted) or fail (> 48 lines adjusted or could not adjust due to poor image quality).
- The frequency of each edit classification was assessed for each volume setting.
- Thickness, paired difference and 95% limits of agreement of each anatomic quadrant were compared across volumes.

Results

Table 1. Magnitude and Frequency of Automated Segmentation Errors Requiring Manual Correction in Children Undergoing SD-OCT of Different Volumes.

Automated Segmentation Errors	OCT Volumes		
	1	3	9
Minor	22	71	72
Moderate	24	3	3
Severe	17	0	0
Fail	12	1	0
Total	75	75	75

Minor: less than 12 lines adjusted; Moderate: >12 and <25 lines adjusted; Severe: >26 and < 48 lines adjusted; Fail: > 48 lines adjusted or could not adjust due to poor image quality.

Table 2. 3mm (N1_INNER) Retinal Layer Thickness Measures Following Manual Segmentation Correction.

Retinal Layer and Sector	9 versus 3 Volume Scans		3 versus 1 Volume Scans	
	Mean Paired Difference, Mean ± SE	95% Limits of Agreement	Mean Paired Difference, Mean ± SE	95% Limits of Agreement
TRT				
Superior	0.9 ± 0.2	-3.4 to 5.2	0.8 ± 0.2	-3.2 to 5.0
Nasal	0.8 ± 0.4	-6.3 to 7.9	1.4 ± 0.8	-11.5 to 14.4
Inferior	0.8 ± 0.3	-4.3 to 6.0	0.3 ± 0.3	-4.7 to 5.4
Temporal	0.9 ± 0.4	-6.1 to 8.0	1.0 ± 0.6	-8.5 to 10.6
RNFL				
Superior	0.1 ± 0.2	-4.1 to 4.3	0.7 ± 0.2	-2.9 to 4.4
Nasal	-0.2 ± 0.2	-3.8 to 3.4	0.5 ± 0.2	-3.5 to 4.5
Inferior	0.0 ± 0.2	-4.5 to 4.6	0.3 ± 0.2	-3.8 to 4.4
Temporal	0.0 ± 0.1	-2.7 to 2.8	0.3 ± 0.2	-3.1 to 3.8
GCIPL				
Superior	0.6 ± 0.2	-3.5 to 4.8	0.4 ± 0.2	-3.7 to 4.6
Nasal	1.1 ± 0.3	-5.1 to 7.3	1.3 ± 0.6	-9.1 to 11.8
Inferior	0.7 ± 0.2	-4.1 to 5.5	0.3 ± 0.2	-4.1 to 4.7
Temporal	0.6 ± 0.4	-6.1 to 7.4	1.0 ± 0.5	-7.7 to 9.9
INL				
Superior	-0.6 ± 0.3	-5.8 to 4.6	-2.4 ± 0.7	-15.1 to 8.8
Nasal	-0.8 ± 0.2	-5.0 to 3.2	-1.9 ± 0.7	-14.4 to 9.4
Inferior	-1.1 ± 0.2	-5.3 to 2.9	-1.0 ± 0.3	-8.4 to 1.2
Temporal	-1.2 ± 0.2	-5.9 to 3.5	-1.3 ± 0.7	-12.8 to 9.0
OPL				
Superior	-0.2 ± 0.9	-16.8 to 16.3	-0.2 ± 0.8	-14.0 to 13.4
Nasal	0.0 ± 0.3	-5.0 to 5.1	-1.1 ± 0.5	-10.2 to 5.7
Inferior	0.0 ± 0.5	-8.9 to 8.9	0.2 ± 0.5	-8.4 to 9.0
Temporal	0.0 ± 0.4	-7.8 to 7.8	-0.2 ± 0.5	-9.2 to 8.2

TRT = total retinal thickness; RNFL = retinal nerve fiber layer thickness; GCIPL = ganglion cell-inner plexiform layer; INL = inner nuclear layer; OPL = outer plexiform layer.

Conclusions

- SD-OCT volume scans without averaging (i.e., ART 1 volume) resulted in many more automated segmentation errors than volumes acquired with averaging (i.e., ART of 3 or 9).
- Fifteen percent of ART 1 volume scans failed automated segmentation completely despite having the appearance of a good acquisition and an acceptable image quality score.
- Once ART 1 volume scans were manually corrected, some but not all of the results were similar to the ART 3 and ART 9 volume scans.
- ART 3 volume scans, which are acquired in one-third the time of an ART 9 volume scan, required the same amount of manual adjustment to the segmentation.
- Once ART 3 and 9 volume scans were manually corrected, there was no appreciable difference in thickness measures, thereby arguing that greater volume averaging is unnecessary.
- In children, a minimum of 3 SD-OCT volumes should be obtained to reduce retinal layer segmentation errors. All SD-OCT automated segmentation results should be reviewed for errors.

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