OCT angiography of ONH blood flow in glaucoma

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Dr. D. Huang has a significant financial interest in Optovue, a company that may have a commercial interest in the results of this research and technology. This potential individual conflict of interest has been reviewed and managed by OHSU.
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Carl Zeiss Meditec, Inc.: patent royalty

OCT captures tissue function as well as structure

<table>
<thead>
<tr>
<th>Signal</th>
<th>Information</th>
<th>En Face</th>
<th>Cross Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflectance</td>
<td>Anatomy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Doppler shift (between consecutive A-scans)</td>
<td>Total retinal blood flow (global circulation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decorrelation (between consecutive B-scans)</td>
<td>Angiography (local circulation)</td>
<td></td>
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</tr>
</tbody>
</table>

Structural OCT

Functional OCT

David Huang, MD, PhD www.COOLLab.net
Ultrahigh-Speed Swept-Source OCT

Developed by MIT Optic & Quantum Electronic Group (Fujimoto) and OHSU Center for Ophthalmic Optics and Lasers (Huang)

Performance features:
- 100,000 axial scans/sec
- 1050 nm tunable laser (deep penetration)
- 5.3 \( \mu \)m axial resolution in tissue

Potsaid B, et al., Optics Express 2010; 18:20029

OCT amplitude-decorrelation angiography uses intrinsic contrast – no dye injection!

Problem: 8 frames at one position do not provide sufficient angiography quality
Solution: Split-Spectrum Amplitude Decorrelation (SSADA) Algorithm

8 frames at one position now provides good angiography quality

SSADA improves signal to noise ratio of flow detection

Split-spectrum amplitude-decorrelation angiography with optical coherence tomography. Optics Express 2012; 20:4710
Comparison of Angiography Algorithms

Full-Spectrum Amplitude Decorrelation

More continuous microvascular network

Split-Spectrum Amplitude Decorrelation

Less Noise >2x SNR


Motion error can be removed with 3D registration of x-fast and y-fast scans

Kraus et al. Biomedical Optics Express 2012; 3:1182
**3D OCT angiography of optic nerve head**

SSADA algorithm used

3x3x3 mm OCT 3D angiography acquired in a 3-second scan

Reflectance (Structure)  
Decorrelation (Flow)


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**OCT Angiography of the Optic Nerve Head – Layer by Layer**

SSADA algorithm used

3x3x3 mm OCT 3D angiography acquired in a 3-second scan

Pilot Study Subject Characteristics

- **Normal**
  - 20 eyes of 20 subjects
  - Age: 50 ± 9 years (mean ± SD)

- **Glaucoma**
  - 10 eyes of 10 subjects
  - 6 perimetric glaucoma, 3 pre-perimetric glaucoma, 1 suspect (ocular hypertension)
  - Age: 66 ±10 years

Variability of Disc Flow Index
(2x 2y registered OCT angiogram)

**Normal Subjects**

<table>
<thead>
<tr>
<th>Intra-Visit Repeatability (n = 3)</th>
<th>Inter-Subject Variability (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1%</td>
<td>4.8%</td>
</tr>
</tbody>
</table>

Less variable than OCT NFL measurement!
Glaucoma reduced ONH flow index

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal</th>
<th>Glaucoma</th>
<th>P Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual field</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean deviation (dB)</td>
<td>0.05 ± 0.84</td>
<td>-2.17 ± 2.57</td>
<td>0.0022</td>
</tr>
<tr>
<td>Pattern standard deviation (dB)</td>
<td>1.43 ± 0.21</td>
<td>3.26 ± 2.31</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Structure (cSLO)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rim area (mm²)</td>
<td>1.61 ± 0.23</td>
<td>1.26 ± 0.29</td>
<td>0.0062</td>
</tr>
<tr>
<td>Cup/Disc area ratio</td>
<td>0.10 ± 0.08</td>
<td>0.31 ± 0.18</td>
<td>0.0025</td>
</tr>
<tr>
<td><strong>Blood flow</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disc flow index</td>
<td>0.163 ± 0.008</td>
<td>0.132 ± 0.022</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Numbers displayed are mean ± population standard deviation; cSLO, scanning laser ophthalmoscopy

* Wilxson rank sum

Glaucoma caused a -19% drop of blood flow in optic disc

David Huang, MD, PhD, John Morrison, MD, Yali Jia, PhD  www.AIGStudy.net

OCT Angiography Showing Reduced ONH Blood Flow in Pre-Perimetric Glaucoma

Normal (OS)

Preperimetric Glaucoma (OS)

ONH flow index = 0.159

ONH flow index = 0.125

David Huang, MD, PhD, John Morrison, MD, Yali Jia, PhD  www.AIGStudy.net
ONH flow index vs. visual field

\[ R = -0.81 \]

Difference between normal and glaucoma not due to age, cup/disc ratio or rim area

David Huang, MD, PhD, John Morrison, MD, Yali Jia, PhD  www.AIGStudy.net
Summary & Conclusions

• ONH microcirculation is reduced in glaucoma
• Pre-perimetric changes can be detected by quantitative OCT angiography
• ONH flow index can be measured with high repeatability: 1.1 % CV
• Variability is small among normals: 4.8% CV
• OCT angiography with the SSADA algorithm may be a useful new tool in the evaluation of glaucoma

OCT Angiography (SSADA) v. Fluorescein/ICG Angiography

OCT Advantages

• 3 dimensional
  – Easily separates disc, retinal, and choroidal circulations
  – Sections & projections along any plane
• Quantitative
  – Flow index
• No injection
  – No vomiting or anaphylactic reaction

OCT Disadvantages

• Small field (3 mm)
  – Field will increase with higher speed
• No visualization of leakage and stain
  – But can visualize fluid space and thickening

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