Optical Coherence Tomography

Rush Center for Neuroendovascular surgery
Disclosure Information

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*Off label use of products may be discussed in this presentation.*
• Optical Coherence Tomography (OCT) is an imaging modality able to provide high-resolution images of vessels \textit{in vivo}.

• While intravascular ultrasound (IVUS) uses backscattered ultrasound, OCT uses reflected light to create cross sectional images of the vessel.
The C7-XR™ OCT Imaging System

- Dual monitors and remote output for multiple sight lines
- Easy mouse and keyboard control
- Multiple export options including RW/DVD
- Small footprint for easy placement

C7 Dragonfly™ Imaging Catheter

Guidewire exit port
Proximal marker
Distal tip marker
20 mm span for segment length assessment
Optical lens in forward position ready for an imaging pullback
C7 Dragonfly™ Imaging Catheter

- Quick-connect hub
- 3 c.c. purge syringe
- 0.035"/2.7 F with hydrophilic coating
- 2.7 F shaft
- Lens
- Lens marker
- 2 cm mini-rail
- Guidewire exit port
- Tip marker
Imaging Lens

Beam is redirected orthogonal to axis
**A Simple and Fast Procedure**

- Cross with C7 Dragonfly™ monorail imaging catheter
- Inject 10-12cc of contrast
- The automatically triggered imaging scan is performed in less than five seconds
OCT in Medical Imaging

Resolution (m)

$10^{-1}$ $10^{-2}$ $10^{-3}$ $10^{-4}$ $10^{-5}$ $10^{-6}$ $10^{-7}$

mm μm

CT/MRI
Ultrasound
OCT
Microscopy
Human Eye
Electro-microscopy

{ 3D

{ 2D
### Common Cardiovascular Imaging Modalities

<table>
<thead>
<tr>
<th></th>
<th>Mechanism</th>
<th>2D/3D</th>
<th>Resolution</th>
<th>Penetration</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Angiography</strong></td>
<td>X-ray attenuation by contrast</td>
<td>2D</td>
<td>~100 um</td>
<td>All body</td>
<td>Blood vessel narrowing</td>
</tr>
<tr>
<td><strong>CT</strong></td>
<td>Tissue x-ray attenuation</td>
<td>3D</td>
<td>~ 500 um</td>
<td>All body</td>
<td>Calcification of vessel wall</td>
</tr>
<tr>
<td><strong>Intravascular MR</strong></td>
<td>Tissue hydrogen content. Hydrogen atoms’ spin</td>
<td>1D</td>
<td>NA</td>
<td>1-5 mm</td>
<td>Lipid content in vessel wall</td>
</tr>
<tr>
<td><strong>Intravascular ultrasound</strong></td>
<td>Sound wave reflection/scattering due to mechanical properties</td>
<td>3D</td>
<td>100-200um</td>
<td>5-10mm</td>
<td>Vessel narrowing, plaque formation and composition, stents</td>
</tr>
<tr>
<td><strong>Anigrography</strong></td>
<td>Reflection properties of vessel wall surface</td>
<td>2D</td>
<td>~ 10 um</td>
<td>Surface imaging, need blood clearing</td>
<td>Thrombus, epithelial damage</td>
</tr>
<tr>
<td><strong>OCT</strong></td>
<td>Optical scattering, absorption and birefringence of vessel wall</td>
<td>3D</td>
<td>10-20 um</td>
<td>1-2 mm Need blood clearing</td>
<td>Vessel narrowing, plaque formation and composition, thrombus, epithelial damage, stents</td>
</tr>
</tbody>
</table>
## Comparison of Imaging Modalities

<table>
<thead>
<tr>
<th>Image Modality</th>
<th>Resolution</th>
<th>Fibrous Cap</th>
<th>Lipid Core</th>
<th>Calcium</th>
<th>Thrombus</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVUS</td>
<td>100μm</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Angioscopy</td>
<td>Unknown</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>+++</td>
</tr>
<tr>
<td>OCT</td>
<td>10μm</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Thermography</td>
<td>.5mm</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Spectroscopy</td>
<td>not applicable</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>—</td>
</tr>
<tr>
<td>Intravascular MRI</td>
<td>160μm</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>

**SENSITIVITY KEY**

+++ = >90%  
++  = 80%~90%  
+   = 50%~80%  
-   = <50%

*Journal of Atherosclerosis, Thrombosis and Vascular Biology 2003;23:1333-1342*
<table>
<thead>
<tr>
<th>Category</th>
<th>IVUS</th>
<th>OCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution (axial)</td>
<td>100 - 150 μm</td>
<td>10 μm</td>
</tr>
<tr>
<td>Resolution (lateral)</td>
<td>150 - 300 μm</td>
<td>25 - 40 μm</td>
</tr>
<tr>
<td>Scan Area</td>
<td>10 - 15 mm</td>
<td>6 - 7 mm</td>
</tr>
<tr>
<td>Penetration depth</td>
<td>4 - 8 mm</td>
<td>1.5 – 2 mm</td>
</tr>
<tr>
<td>Blood removal</td>
<td>Not required</td>
<td>Required</td>
</tr>
</tbody>
</table>
Excellent Measurement Accuracy

### In-vitro phantom study

<table>
<thead>
<tr>
<th></th>
<th>OCT</th>
<th>IVUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean diameter error</td>
<td>0.98%</td>
<td>4.75%</td>
</tr>
<tr>
<td>Max diameter error</td>
<td>2.86%</td>
<td>14.00%</td>
</tr>
<tr>
<td>Mean area error</td>
<td>1.87%</td>
<td>9.53%</td>
</tr>
<tr>
<td>Max area error</td>
<td>5.72%</td>
<td>32.18%</td>
</tr>
</tbody>
</table>

Data on file: AQ/LLI/DOCS/14437
FACT™
Focused Acoustic Computed Tomography

New Transducer Technology

Design Goals
• Sub 50 micron axial resolution
• Visualization of entire plaque and vessel wall without needing to flush to clear blood
<table>
<thead>
<tr>
<th>Advantages of OCT</th>
<th>Clinical demands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest resolution in all in vivo imaging technology (10-20µm)</td>
<td>Stent evaluations</td>
</tr>
<tr>
<td>Correlation with histology and other intravascular modalities (IVUS, angioscopy)</td>
<td>Vessel measurement</td>
</tr>
<tr>
<td>Lumen contour detection</td>
<td>Post stenting evaluation</td>
</tr>
<tr>
<td>Easy, very fast, reproducible</td>
<td>New stent development</td>
</tr>
<tr>
<td></td>
<td>Stent “healing”</td>
</tr>
<tr>
<td></td>
<td>Vulnerable plaque</td>
</tr>
<tr>
<td></td>
<td>Thin cap (&lt;65µm)</td>
</tr>
<tr>
<td></td>
<td>Macrophages</td>
</tr>
<tr>
<td></td>
<td>Lipid</td>
</tr>
<tr>
<td></td>
<td>(Macro) Calcification</td>
</tr>
<tr>
<td></td>
<td>Thrombosis detection</td>
</tr>
</tbody>
</table>
OCT for stent evaluation

Follow up

Strut apposition

Strut coverage
New implanted stents

Stent follow-up (neointima growth)
Side branch detection

False lumen

Intima tear
OCT Tissue Characterization Preliminary Results

**OCT image features:**
1. Signal intensity
2. Attenuation
3. Edge sharpness
4. Texture

**Histology features:**
1. Staining colors
2. Cellular morphology
Thin-cap Necrotic Core

TCFA without macrophage infiltration: Two-layer structure. Diffuse boundary formed by the cap and the underlying core.
Atherosclerotic plaque composition

Fibrous
Homogeneous signal-rich region

Fibrocalcific
Well-delineated, signal-poor region with sharp borders

Lipid-rich
Signal-poor region with diffuse borders

Sensitivity and specificity: 71-79% and 97-98% for fibrous, 95-96% and 97% for fibrocalcific and 90-94% y 90-92% for lipid-rich plaques.

OCT for the evaluation of new generation stents

Bioabsorbable stents

- The prospective, multicenter, ABSORB study evaluated the safety and efficacy of a fully absorbable everolimus eluting stent (BVS*) for the treatment of de novo single coronary stenosis.
- OCT substudy in Rotterdam after implantation, at 6 months and 2 years.

*Serruys et al. Lancet 2009; 373: 897–910

*Bioabsorbable Vascular Solutions, Inc, an affiliate of Abbott Laboratories, located in Mountain View, CA
Precise Vessel Measurement

A Area: 9.34mm²
Mean Diameter: 3.44mm
Min: 3.17mm, Max: 3.72mm
Neuro Plaque
MCA – Lenticulostriate perforators
MCA – Lenticulostriate perforators
Relationship pipeline - perforator
Basilar post Pipeline

<< 29.9 mm, 5.0 mm/sec
P-com artery (smallest)
Transverse sinus imaging
Stent endothelialization monitored with intravascular imaging and histology in porcine
Results - 4 days

- Endothelialization: FLEX (5 × 12mm) vs. FLEX with Shield (5 × 12mm) vs. Solitare (5 × 20mm) (1Fr.=0.1mm)
Endothelialization of device over time in a porcine model
Thank you