Endoscopic Optical Coherence Tomography

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Endoscopic OCT at GWU
- OCT imaging of the urinary bladder
- Texture analysis of OCT images for cancer detection and staging
- Basic research in new scanning probes using MEMS technology

Optical Coherence Tomography (OCT)
- Imaging modality analogous to ultrasound or radar, but measures reflected infrared light
- As small as 4 µm resolution, but only 2-3 mm of penetration in tissue
- Has cell level resolution, could be used as an ‘Optical Biopsy’ technique – more likely to be used to guide biopsy procedures
- Applications include eye, skin, intravascular (imaging arterial plaques) and endoscopic imaging (esophagus, cervix, mouth, bladder, etc.)


OCT Block Diagram

- BroadBand Optical Source
- Optical Circulator
- Delay Line
- Sample
- Scanning Arm
- Computer
- Frame Grabber
- Envelope Detector
- Differential Detector Module
- 50/50 Optical Circulator
- Fiber and Collimator
OCT in Bladder Cancer

- We are working with Dr. Michael Manyak and Imalux Corporation in a clinical trial to investigate the use of OCT in bladder cancer.
- 24 patients undergoing bladder biopsy were investigated (87 sites imaged).
- Both normal and suspicious areas of the bladder were photographed, imaged with OCT, and then biopsied.
- Biopsy results were compared with diagnoses from OCT images.
- Results were promising, but diagnosis from OCT images can be problematic.

87 images evaluated, this data included:
16 papillary tumors, 36 suspicious areas, 35 suspected normal

Sensitivity 100 %
Specificity 77 %
PPV 75 %
NPV 100%
Accuracy 92 %
PPV for invasion 90%

Texture Analysis of OCT Images

- Identification of precancerous and cancerous conditions in OCT images can be a difficult task
- We are investigating methods to examine the underlying texture of the OCT images to try and diagnose various conditions (dysplasia, inflammation, carcinoma in situ, invasive cancer, etc.)
- Early results are extremely promising

Results of Algorithm

<table>
<thead>
<tr>
<th>Pathology Results</th>
<th>Decision</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>20</td>
<td>87%</td>
<td>95%</td>
</tr>
<tr>
<td>Exudative Inflammation</td>
<td>21</td>
<td>80%</td>
<td>87%</td>
</tr>
<tr>
<td>Infiltrative Inflammation</td>
<td>42</td>
<td>47%</td>
<td>78%</td>
</tr>
<tr>
<td>Dysplasia</td>
<td>0</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>CIS</td>
<td>0</td>
<td>100%</td>
<td>95%</td>
</tr>
<tr>
<td>Invasive Tumor</td>
<td>2</td>
<td>78%</td>
<td>95%</td>
</tr>
<tr>
<td>Papillary Lesion</td>
<td>2</td>
<td>78%</td>
<td>95%</td>
</tr>
<tr>
<td>Total Non-Cancerous</td>
<td>89</td>
<td>62%</td>
<td>95%</td>
</tr>
<tr>
<td>Total Cancerous</td>
<td>3</td>
<td>92%</td>
<td>95%</td>
</tr>
</tbody>
</table>


Conclusions: Texture Analysis

- Viable method of OCT image evaluation
- Highly sensitive to distinguish dysplasia/CIS from normal
- Highly specific for normal and exudative inflammation
- Low specificity for diffuse inflammation vs cancer
- We are working on new “smart” algorithms that are not affected by variation in system parameters.

Microfabricated Scanners in OCT

- MEMS devices are fabricated using photolithography so they can be made to be inexpensive and disposable for endoscopic and catheter applications
- Very small devices with low power consumption are possible for catheter and endoscopic applications
- A key size parameter is making probes small enough to pass through the accessory port of a standard endoscope (2.7-5 mm outer diameter)
- Reducing the cost of the probes has the potential to reduce the expense of patient care

Integrated Fabrication

- Fabrication completed with support from the Army Research Laboratory in Adelphi, MD

Microfabricated Imaging Probes

Device In Motion

Encased Imaging Probe

- Patterned Device on Wafer Prior to Back Etch
- Completed Device After Back Etch
- Silicon wafer
- Sacrificial layer
- Variable thickness piezoelectric
- Piezoelectric or other mirror stiffener
- 3 µm polyimide
- 30 µm polyimide
- Gold

- Actuator
- Mirror

- Imaging Window
- Scanning Mirror
- GRIN Lens / Prism
MEMS scanner integrated into scanning arm of OCT scanners, system is different for galvanometer based scanner

Summary

• Bladder cancer imaging with OCT has expanded to a multi-center imaging trial being run by Imalux.
• Texture analysis of images is extremely promising and more robust algorithms are currently being developed.
• Microfabricated imaging probes are being evaluated for scanning performance and ability to guide interventional procedures such as biopsy and laser ablation.

Acknowledgements

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