Optical Coherence Tomography (OCT): Review, Applications and Outlook
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Agenda

• Background
• Current Applications
• Index Patient
• Future Outlook
Background

- Optical coherence tomography is analogous to ultrasound (US)
  - Cross-sectional images are generated by measuring the echo time delay and intensity of infrared light (rather than sound waves)

- Capabilities:
  - Provides axial resolution of 10-15 μm (1 or 2 orders of magnitude greater than US)
    - Some research tools have shown resolution < 5 μm

- Safety:
  - Contact-less imaging modality with no known damage to tissues

- Limitations:
  - Penetration depth of OCT remains the largest limitation
    - Currently, 0.5 to 1.5 mm of imaging depth in most tissue types
  - Second limitation is lack of ability to image through a blood field
OCT schematic

Current Applications

Cardiology

Ophthalmology

Dermatology
Current Applications: Interventional Cardiology

- Confirm the absence of significant atherosclerosis
  - Characterize the substance within plaques
  - Indicate the degree of subclinical atherosclerotic lesion formation
- Evaluate stenoses with greater acuity than intravascular US
- Assess angiographically hazy lesions and focal vessel spasm
- Future applications include:
  - Assessment of allograft vascular disease
  - Measuring plaque vulnerability and progression
Diffusely fibrotic plaque (A), lipid pool (B), calcific component (C), & thrombus (D) [3]
Current Applications: Ophthalmology

- Analysis of neuro-degeneration in multiple sclerosis (MS)
  - Monitor thickness changes of the retinal nerve fiber layer
- Glaucoma imaging
  - Evaluate cup area, disc area, cup diameter, disc diameter, and rim area
- Retinal pigment epithelial detachment
- Diabetic retinopathy
- Assessment of lens thickness
  - Pre- and postsurgical assessment of intracorneal ring placement
- Age-related macular degeneration
  - Measure drusen volume (extracellular material that build up between the innermost layer of the choroid and the retinal pigment epithelium)
OCT visualization of the fovea and underlying retinal layers [2]

Significance maps shows significant increase in ganglion cell thickness in patients with glaucoma [2].
Current Applications: Dermatology

• Differentiating skin tumors from cysts
  – Epithelial skin tumors give off homogenous signal
  – Cystic lesions are identified by signal free areas
  – Melanocytic skin tumors show higher light scattering

• Characterizing inflammatory skin disease
  – Parakeratotic stratum corneum appears as a multilayered thickened entrance signal (e.g. psoriasis)
  – Scales may cause signal shadows due to the total reflection of the light from the surface

• Tracking treatment for various therapeutics on skin
In vivo OCT image of healthy skin of the finger tip [1]

- First layer is the stratum corneum with sweat gland ducts (stars)
- Stratum granulosum is marked by an arrow
- Thickness can then be reproduced without the need for biopsy
Application of glycerol on healthy skin (a) shows increased detection depth and signal enhancement in (b) by decreasing skin reflection [1].

Dermatology: Basal Cell Carcinoma


Basal cell carcinoma on the lower eyelid (increased signal homogeneity) [1]
Dermatology: Hemangioma and Psoriasis

Areas of low signal represent abnormal blood vessels in a hemangioma [1]

Multiple parallel lines show thickened stratum corneum consistent with psoriasis [1]
Index Patient to Consider
Index Patient

62 year old woman with progressive painless loss of vision in the center portion of her eye

Index Patient: Age-related Macular Degeneration

- Atrophy of the retinal pigment epithelial layer below the retina
  - Loss of photoreceptors (rods and cones) in central part of eye
  - Drusen accumulates between the retina & the inner layer of the choroid

AMD with large drusenoid before and after experimental therapy
Summary

• Optical coherence tomography:
  – Analogous to US but uses infrared light instead of sound
  – Promises for greater resolution, but limited by depth penetration
  – Safe and contact-less modality
  – Applications in fields:
    • Ophthalmology
    • Dermatology
    • Intravascular imaging in Cardiology
    • GI imaging
Future Outlook

• Medical:
  – Photonic crystal fibers and super-fluorescent fiber sources may expand the utility of OCT
    • Greater depth and better resolution
  – Applications in oncology to monitor cancer therapy
  – Predict the risk for stroke risk by characterizing plaque vulnerability to rupture or embolization

• Industrial:
  – Material thickness measurements (thin silicon)
  – Surface roughness characterization
  – Surface and cross-sectional characterization of materials
References and Acknowledgements


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