Shuai Xu, MS3
Gillian Lieberman, MD

Beth Israel Deaconess Medical Center

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

Steve Xu, Harvard Medical School Year III

Gillian Lieberman, MD

Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

Agenda

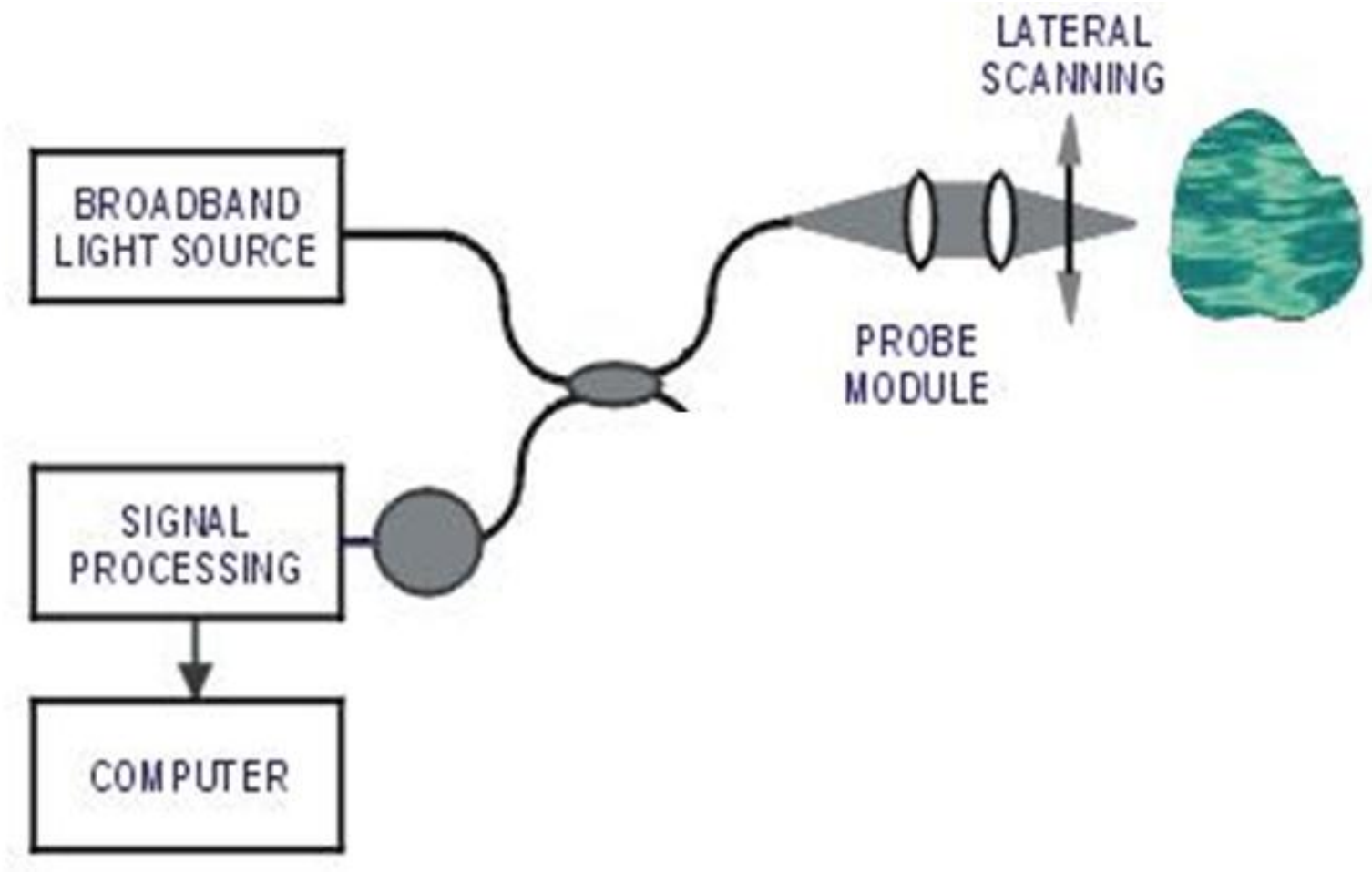
- Background
- Current Applications
- Index Patient
- Future Outlook

Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

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

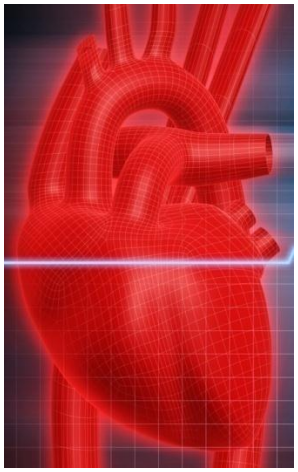


Optical Coherence Tomography (OCT). MIT. http://ocw.mit.edu/courses/mechanical-engineering/2-717j-optical-engineering-spring-2002/syllabus/statops/. Accessed 03/19/2013

Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

Current Applications

Cardiology



Ophthalmology

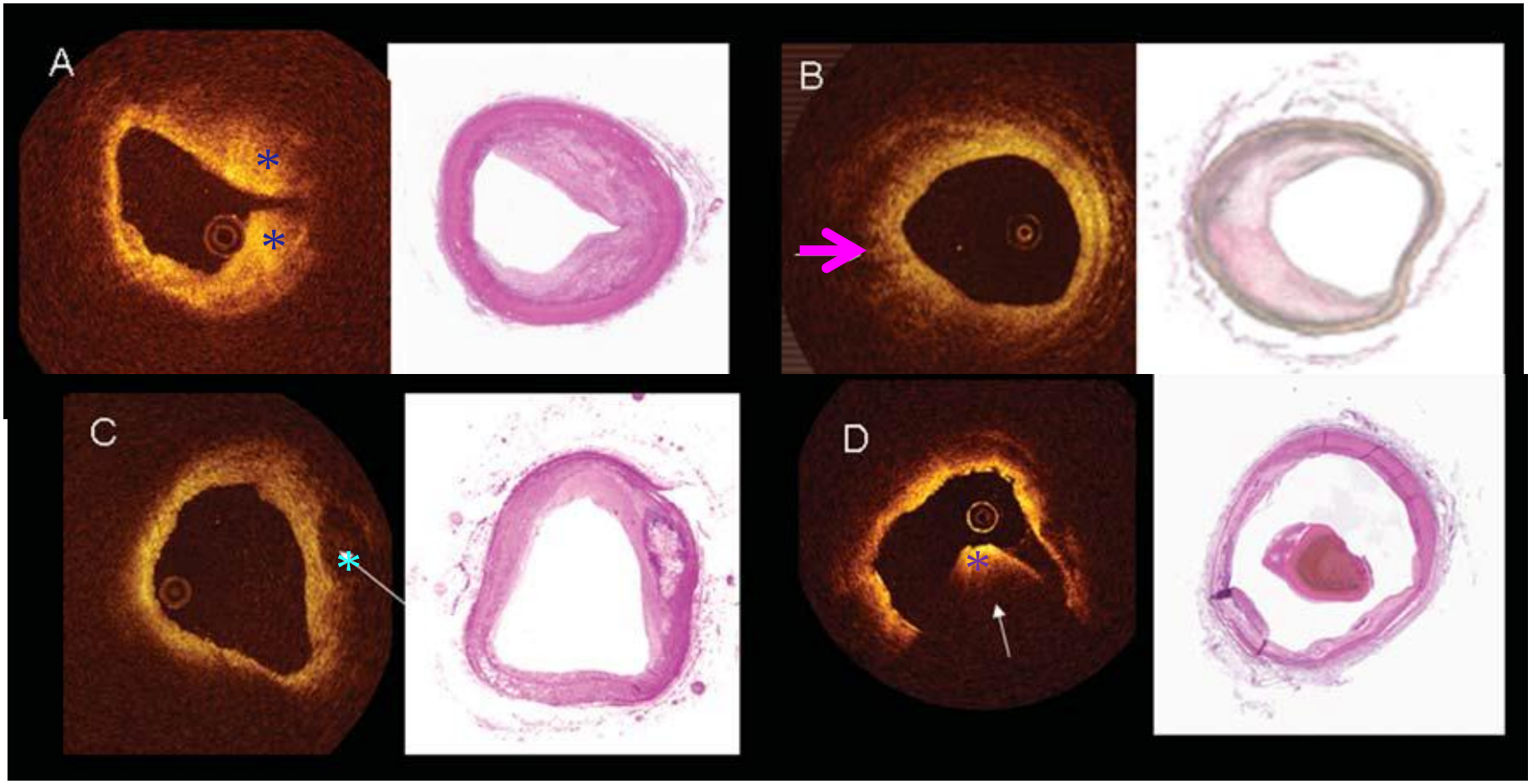
Dermatology

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

Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

Cardiology: Intravascular OCT



Prati , Francesco et al. European Heart Journal. 2010; 31:401-415.

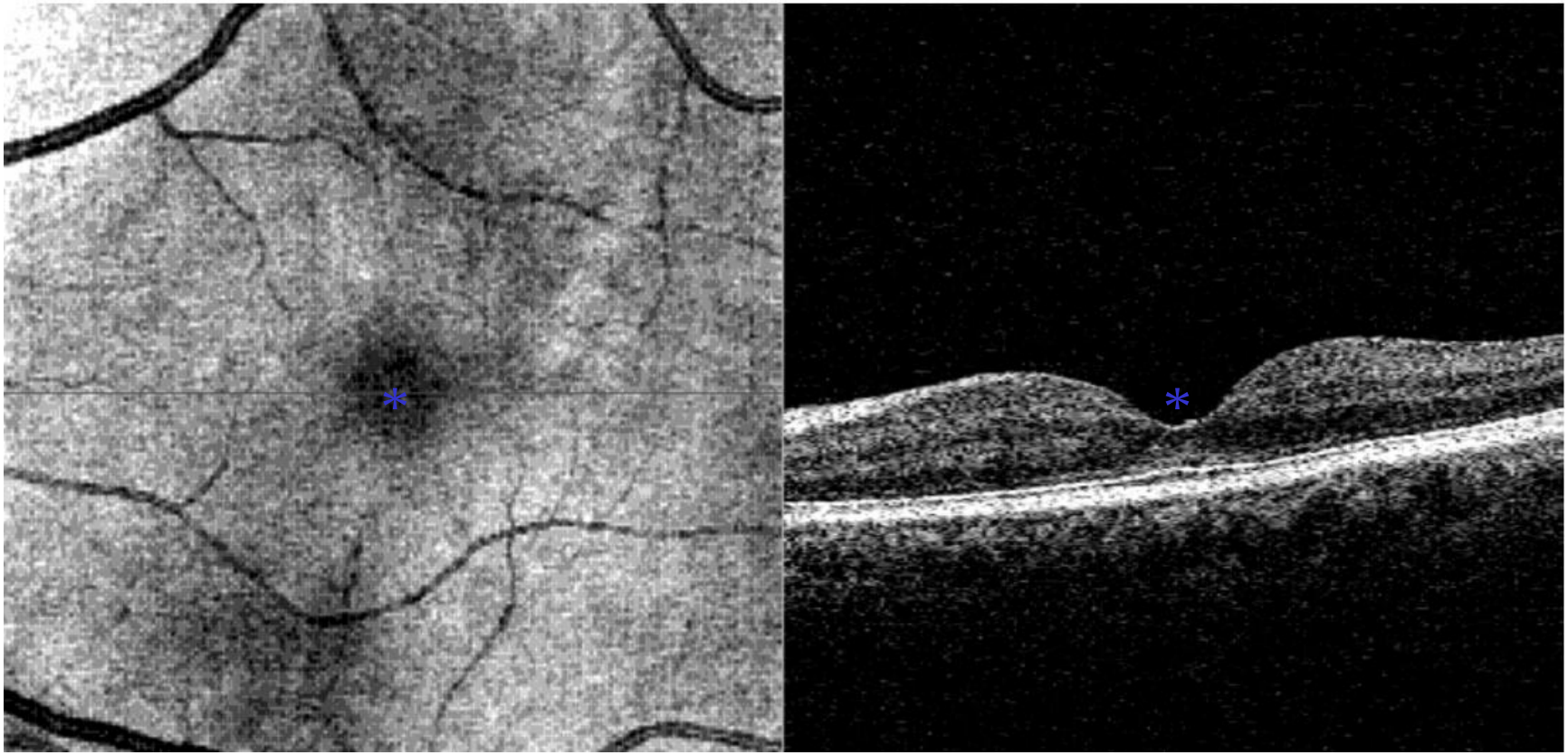
Diffusely fibrotic plaque (A), lipid pool (B), calcific component (C), & thrombus (D) [3]

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)

Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

Ophthalmology: Normal Images

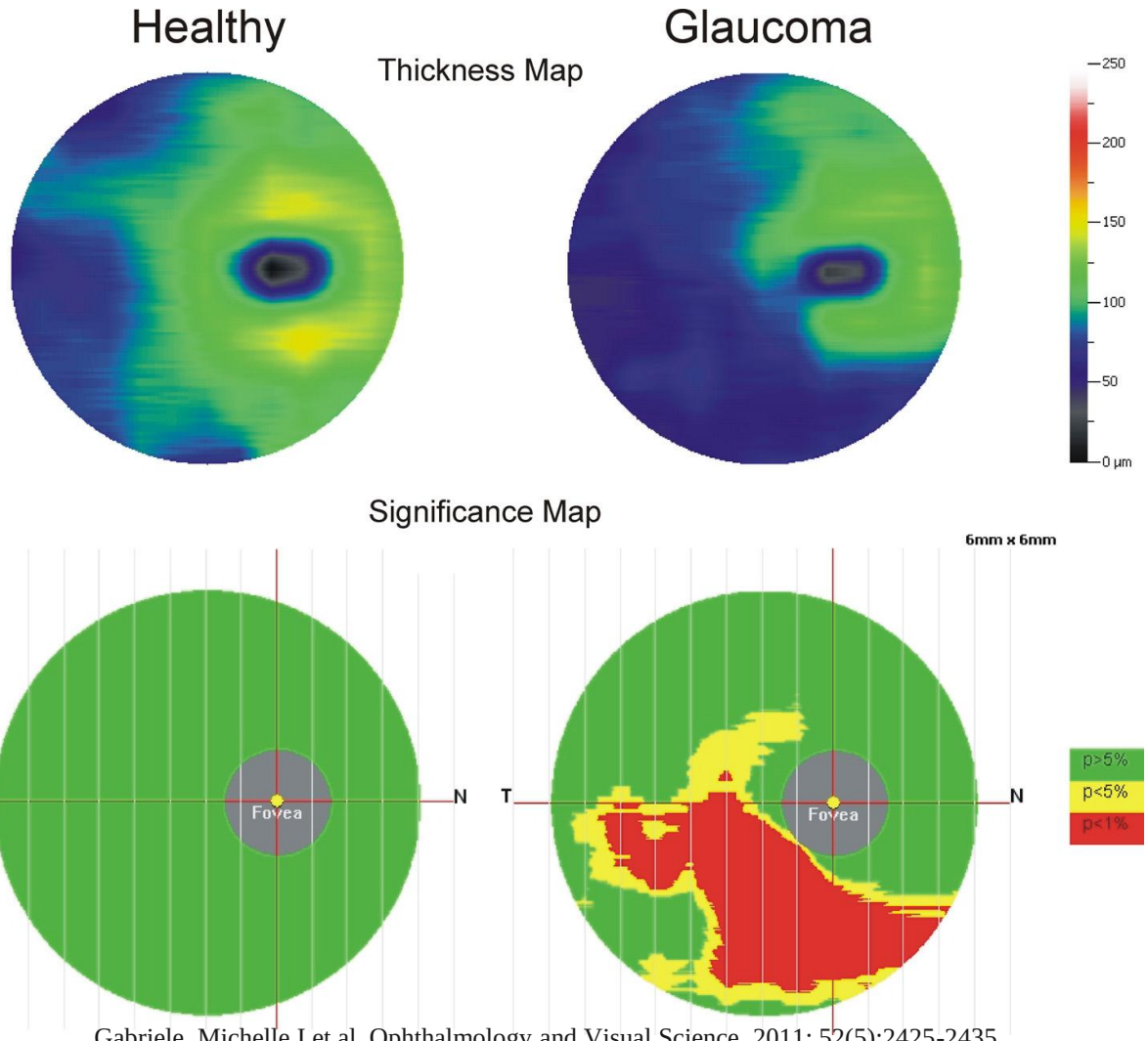


Gabriele, Michelle I et al. Ophthalmology and Visual Science. 2011; 52(5):2425-2435.

OCT visualization of the fovea and underlying retinal layers [2]

Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

Ophthalmology: Glaucoma



Gabriele, Michelle I et al. Ophthalmology and Visual Science. 2011; 52(5):2425-2435.

Significance maps shows significant increase in ganglion cell thickness in patients with glaucoma [2]

BACK

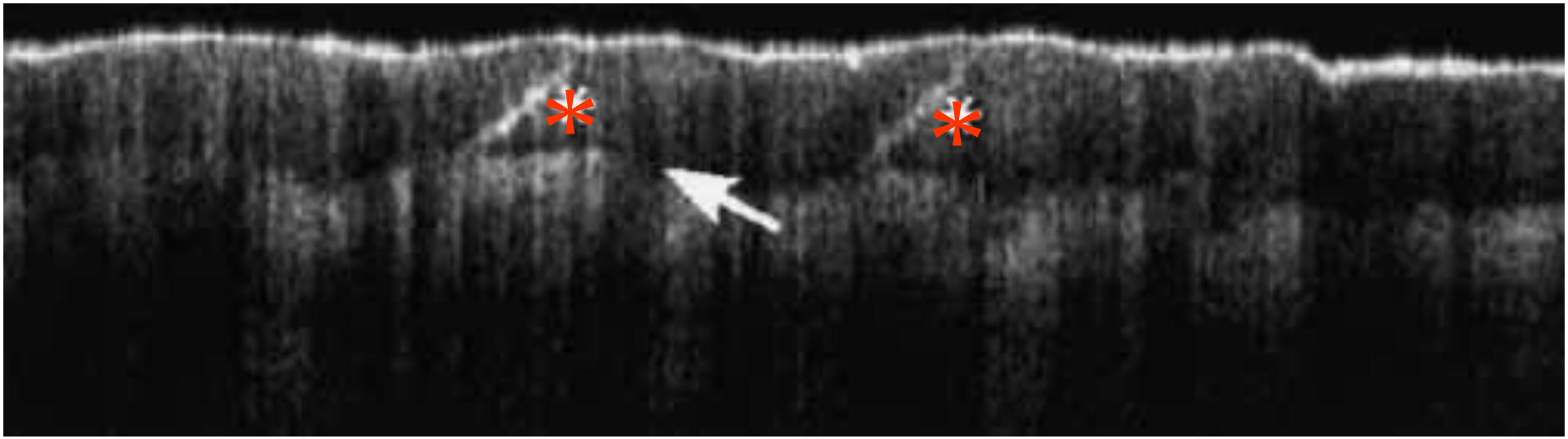
Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

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

Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

Dermatology: Normal Skin



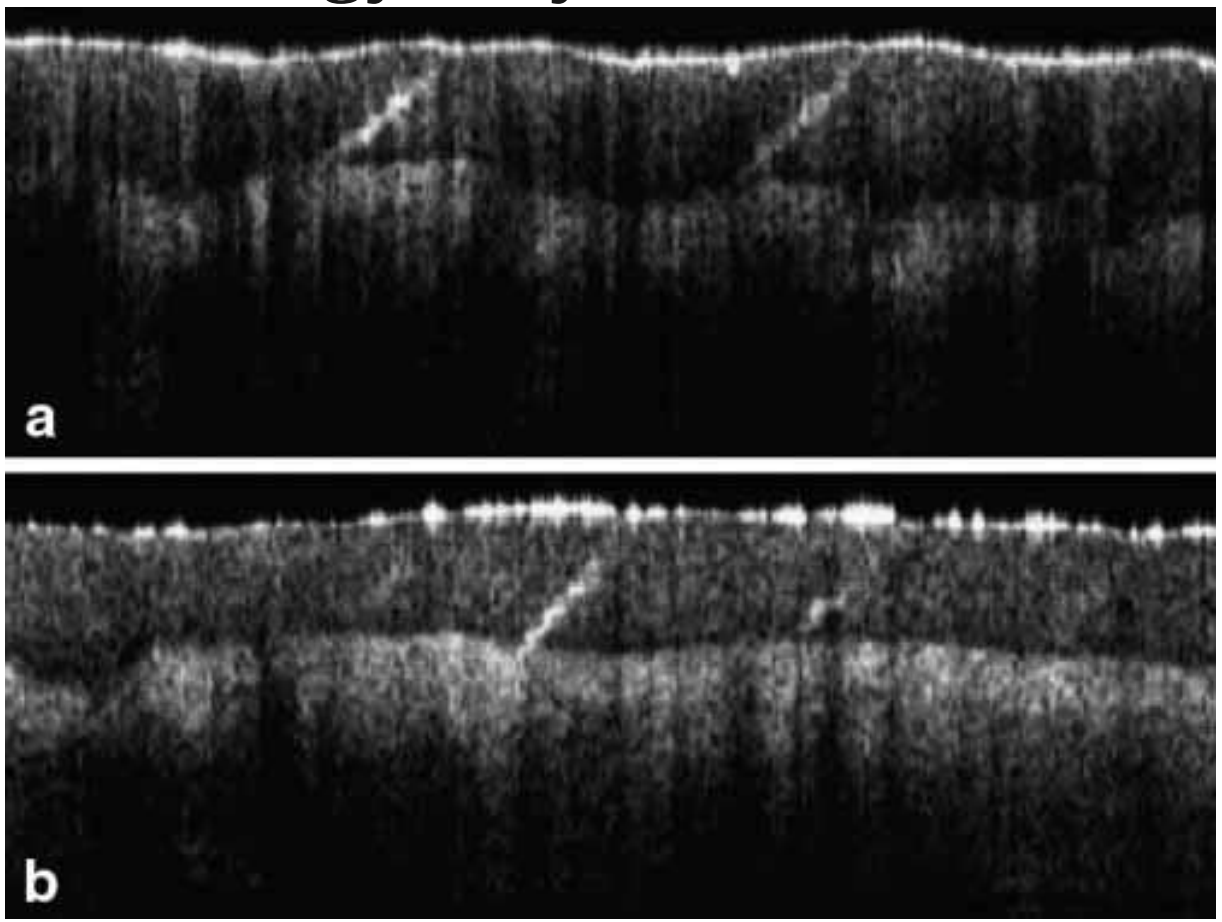
Welzel, Julia. Skin Research and Technology. 2001; 7:1-9.

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

Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

Dermatology: Glycerol Enhancement

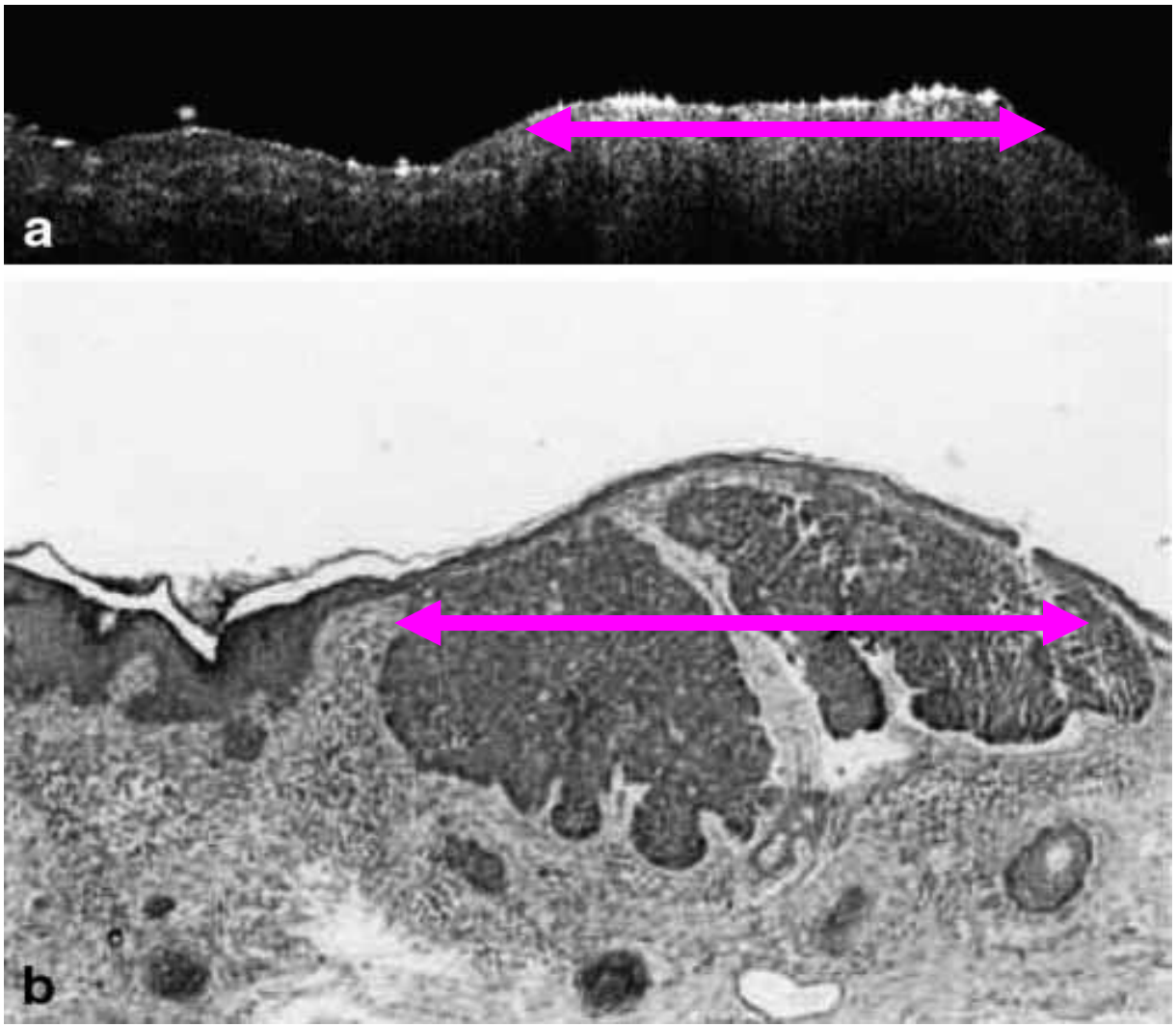


Welzel, Julia. Skin Research and Technology. 2001; 7:1-9.

Application of glycerol on healthy skin (a) shows increased detection depth and signal enhancement in (b) by decreasing skin reflection [1]

Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

Dermatology: Basal Cell Carcinoma

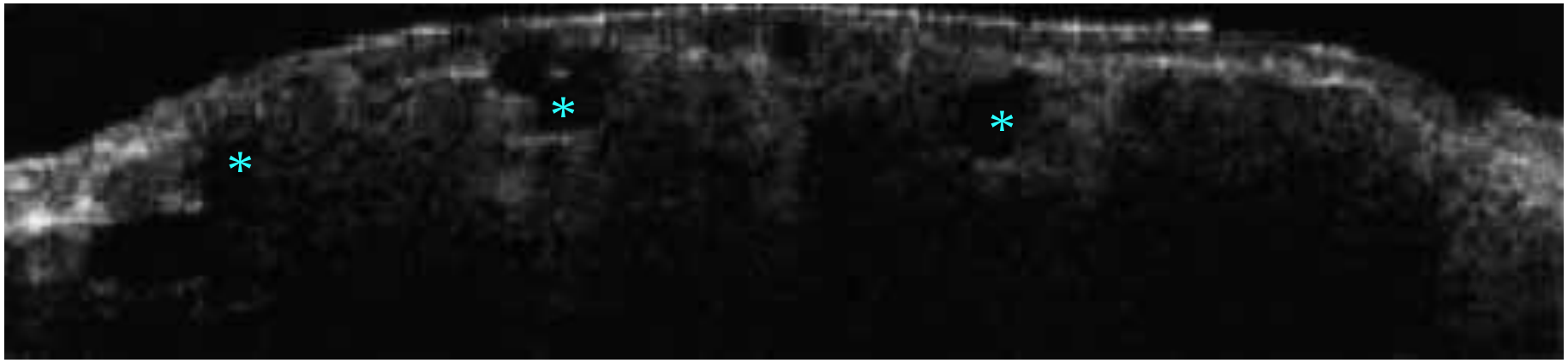


Welzel, Julia. Skin Research and Technology. 2001; 7:1-9.

Basal cell carcinoma on the lower eyelid (increased signal homogeneity) [1]

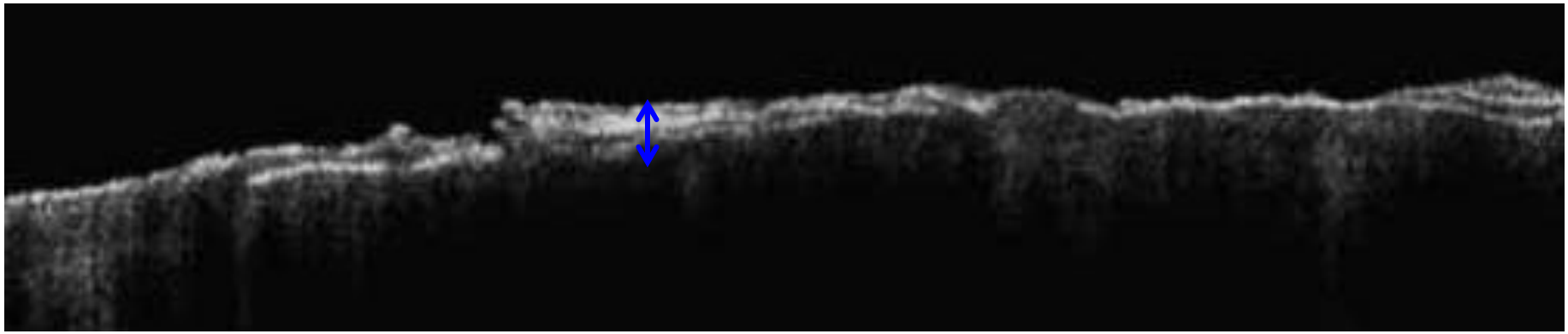
Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

Dermatology: Hemangioma and Psoriasis



Welzel, Julia. Skin Research and Technology. 2001; 7:1-9.

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



Welzel, Julia. Skin Research and Technology. 2001; 7:1-9.

Multiple parallel lines show thickened stratum corneum consistent with psoriasis [1]

BACK

Index Patient to Consider

Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

Index Patient

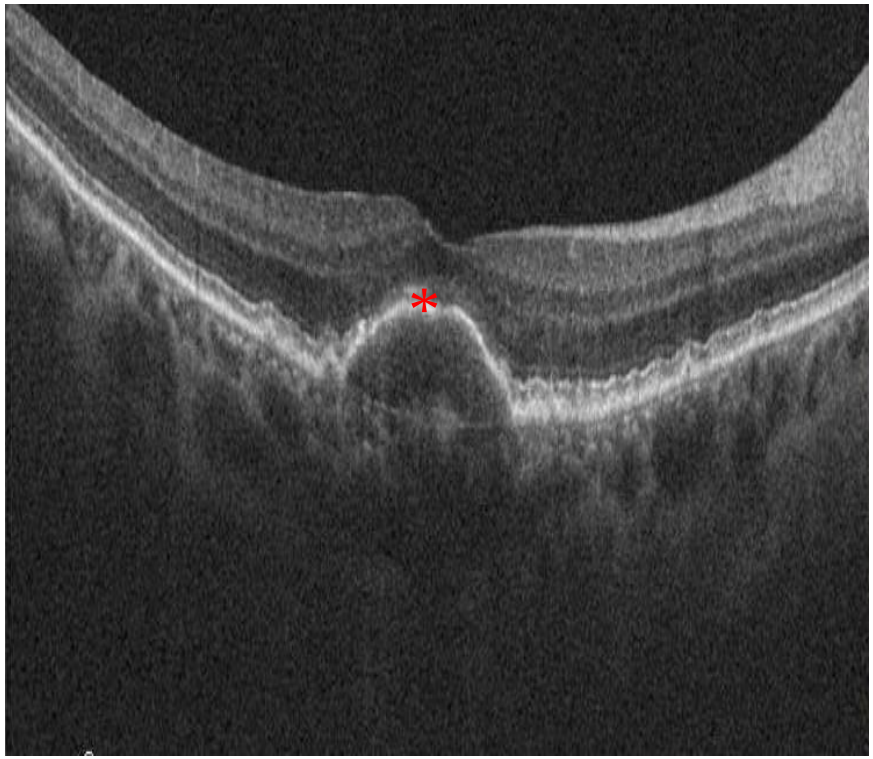
62 year old woman with progressive painless loss of vision in the center portion of her eye

National Eye Institute Homepage. http://www.nei.nih.gov/health/maculardegen/armd_facts.asp, accessed 3/19/13

Beth Israel Deaconess Medical Center
Shuai Xu MS3
Gillian Lieberman, MD

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



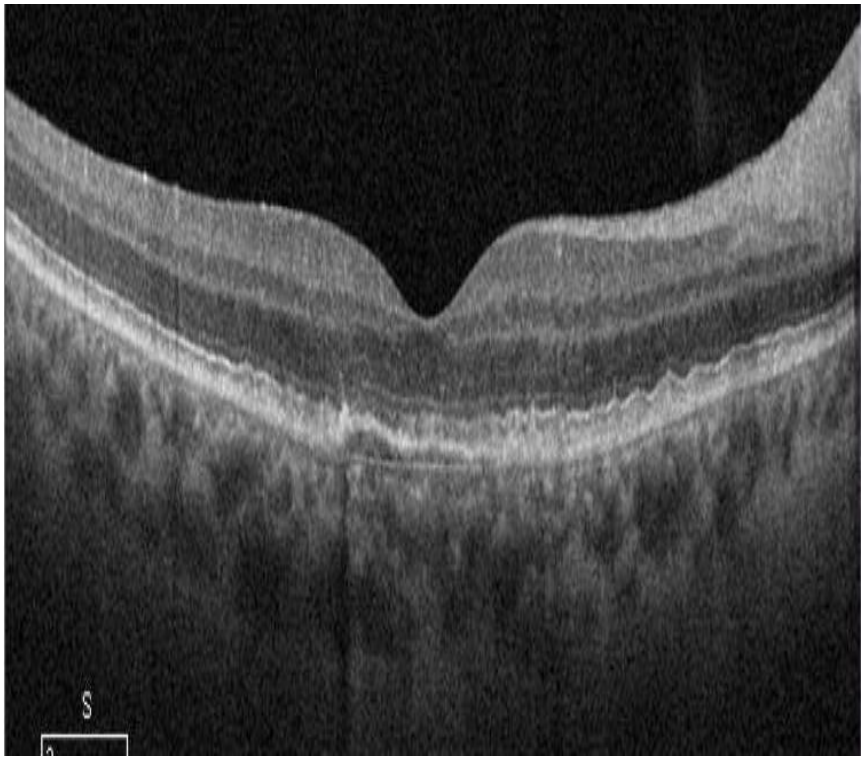


Image courtesy of Dr. Vavvas, MEEI

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

1. Welzel, Julia. Optical coherence tomography in dermatology: a review. Skin Research and Technology. 2001; 7:1-9.
2. Gabriele, Michelle I et al. Optical coherence tomography: history, current status and laboratory work. Ophthalmology and Visual Science. 2011; 52(5):2425-2435.
3. Prati , Francesco et al. Expert review document on methodology, terminology, and clinical applications of optical coherence tomography: physical principles, methodology of image acquisition, and clinical application for assessment of coronary arteries and atherosclerosis. European Heart Journal. 2010; 31:401-415.
4. Vakoc, Benjamin et al. Cancer imaging by optical coherence tomography: preclinical progress and clinical potential. Nature Reviews Cancer. 2012; 12:363-368.
5. Standish B et al. Vascular Wall Imaging of Vulnerable Atherosclerotic Carotid Plaques: Current State of the Art and Potential Future of Endovascular Optical Coherence Tomography. AJNR. 2012; 34(3):1-9

- Thank you to Dr. Vavvas at the MEEI for the index case