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Fiber Architecture Analysis of White Light Fibroid Images

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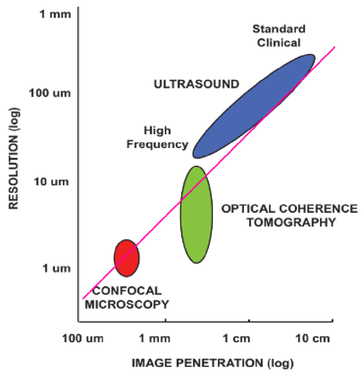
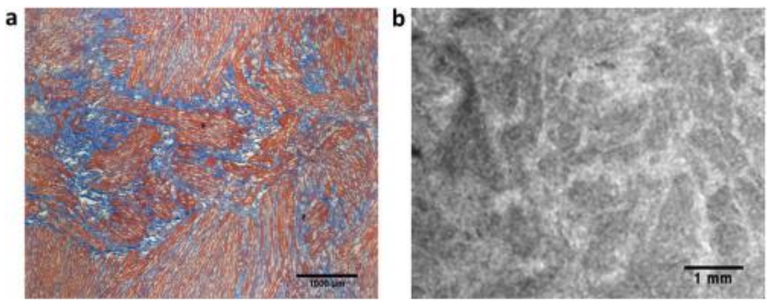
INTRODUCTION

- Current optical tissue imaging techniques used in biomedical and medicinal applications include ultrasound imaging, microscopy, and optical coherence tomography (OCT). OCT provides three-dimensional imaging with approximately 10-micron resolution.



- Fibroids are benign tumors of the uterus that cause pain, and increased bleeding and can impact fertility. Uterine fibroids are very common, however many are diagnosed or treated after years of experiencing symptoms. There are additional challenges when determining whether this abnormality is cancerous or a benign fibroid due to the imaging limitations of the current use of white light endoscopic cameras.
  - Previous work in our laboratory has shown that collagen fiber organization patterns of the uterus can be measured with OCT can be used to identify regions with fibroids.



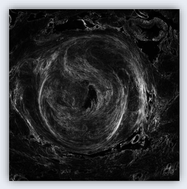
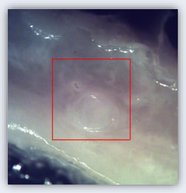
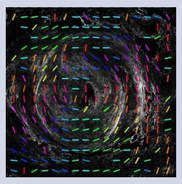
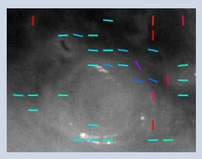
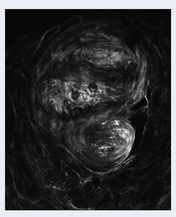
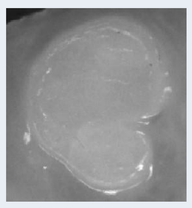
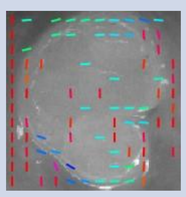
  - This information would allow doctors during basic yearly checkups to treat the patient accordingly.
- Currently, endoscopic techniques are used to view and analyze the uterine tissue.
  - An endoscope is an optical lens utilizing white light used to inspect organs in medical practices.
- Another method of imaging tissue is through second-harmonic generation microscopy (SHG). An SHG is a non linear optical imaging technique.
- The imaging setup used in these research efforts utilized the OCT in the basic white ligh camera configuration and the Thorlabs Telesto system.

OBJECTIVE

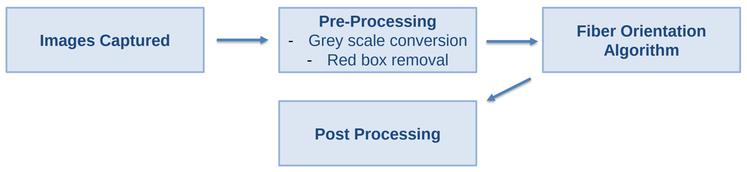
- The primary objective of this research was to explore the viability of utilizing white light camera imaging techniques to measure collagen fiber organization. Collagen is a protein in the body that contributes to the growth of fibroids.

METHODS

- Human uterus samples were obtained under an IRB approved protocol from Columbia University Medical Center after surgery. Samples were imaged with second harmonic generation and optical coherence tomography. Histopathology was conducted to verify the composition of the tissue.
- Using the white light imaging (WLI) corresponding to the OCT field of view, images were taken of the uterus samples and compared to the same images taken using SHG. This was done for two small, seedling fibroids.

	SHG Image	OCT WLI
F5 Sample		
Original Image		
Orientation Map		
	SHG Image	**OCT WLI**
F8 Sample		
Original Image		
Orientation Map		

- Once the camera images were taken, the following flow diagram expresses the various following steps taken to achieve this analytical state. **Process Flow Chart:**



Fiber Orientation Algorithmic Equations

$$G(i,j) = \sqrt{G_x^2(i,j) + G_y^2(i,j)}$$

$$\Phi(i,j) = a\tan(G_y / G_x)$$

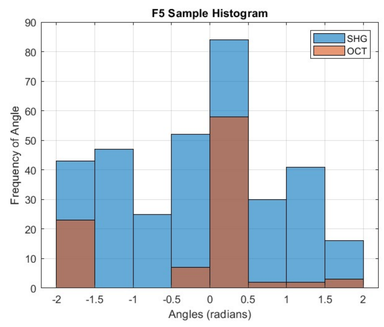
$$P(\omega)^W = \widetilde{P}(\omega)^W / \sum^{179} \widetilde{P}(\omega)^W$$

$$\widetilde{P}(\omega)^W = \sum_{(i,j)\in W} G(i,j) \frac{\exp(2\cos[2(\omega - \Phi(i,j))])}{\exp(2)}$$

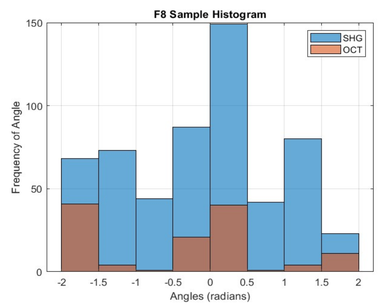
(i, j) = each image pixel
(G_x) = gradient intensity in horizontal direction
(G_y) = gradient intensity in vertical direction
G(i, j) = magnitude of gradient
Φ(i, j) = angle of gradient
W = sub region
ω = estimation of dominant gradient in W

- Final image analysis between the SHG and WLI methods was done utilizing histograms. The x-axis representing the angle in radians, and the y-axis representing the amount the angle can be found across the orientation map.

RESULTS



	SHG	WLI
Mean	-0.1405	-0.2596
Variance	0.9487	0.6770
Skewness	0.0363	-0.3569
Kurtosis	1.9307	2.8211



	SHG	WLI
Mean	-0.3860	-0.1109
Variance	1.0281	0.9532
Skewness	0.2685	0.0223
Kurtosis	2.1384	1.9362

- There are significantly fewer gradient points taken for the camera images when compared to the SHG images.
- The quantitative method of analysis used to compare the histograms took the mean, variance, skewness, and kurtosis of all represented angles of the fiber orientation maps.

DISCUSSION

- The quality of the images dictates how well the fiber orientation map is processed. So, by default the SHG images should have the clearest fiber orientation maps clearly displaying the location of the fibroids and the collogen directionality.
- It is clear based on the WLI results that further pre/post processing efforts could benefit the results. Such as sharpening the images or further distributing the greyscale ranges.
- In the images, “dead space” seems to also interfere with the gradient making algorithm. Further altering the fiber orientation maps to exercise a threshold angle before displaying a gradient could also benefit the results.

FUTURE WORK

- Implementing more pre-processing steps before the fiber orientation algorithm. This includes increasing the signal noise reduction (SNR) for clearer/sharper images.
- Once the pre-processing issues are addressed, taking specific fibroid regions and analyzing the fiber orientations broken down would provide more cohesion between the results.

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