Analyzing human ventricles using optical coherence tomography

COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Structure Function Imaging Laboratory

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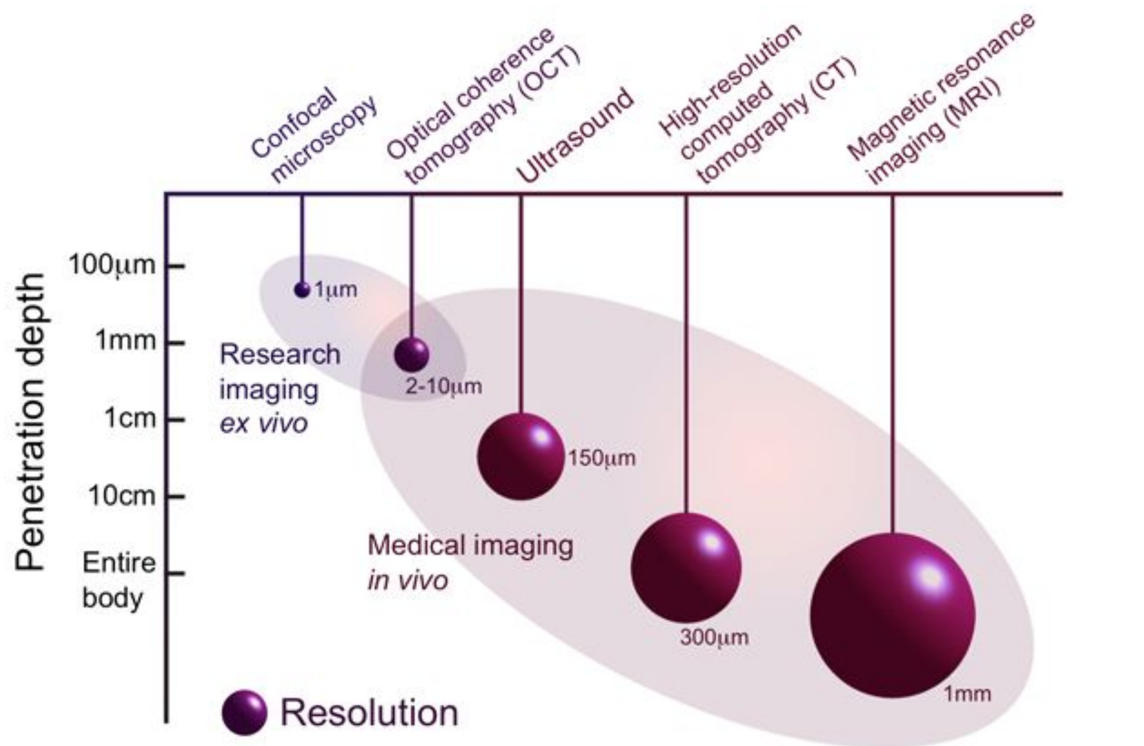
INTRODUCTION

- Heart disease is a common cause of death in the United States, as someone dies every 33 seconds. [2] Ventricular arrythmias are abnormal heartbeats that originate in your lower heart chambers, called ventricles. This cardiac disease is common for those who have heart-related diseases. If left untreated ventricular arrythmias could be deadly.
- Cardiac Ablation was introduced to control arrythmias at low risk. This is carried out during surgery to reduce irregular electrical signals in the ventricles.
- Cardiac ablation occurs in vivo, but there is no real-time guidance. This can result in damage to the tissue.
- Optical Coherence Tomography (OCT) is a volumetric, non-invasive optical imaging technique utilizes near-infrared light to produce volumes of the structures of the cardiac tissue under examination. OCT can be used to determine ablated tissue.[2]
- OCT has also been used to image trabeculations in left atrium of the heart. [3]
- Compared to other optical imaging techniques, such as a CT scan, OCT provides real-time feedback while producing volumetric data for clinical evaluations.



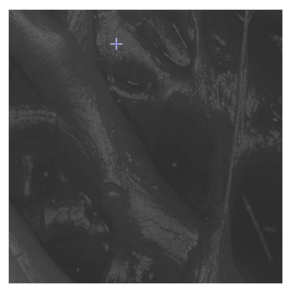
OBJECTIVE

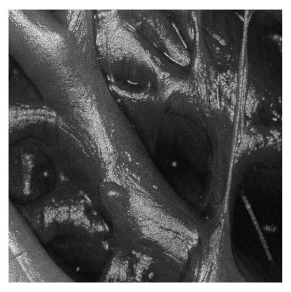
This research aimed to characterize tissue substrates within OCT images of the ventricle that can be potential targets for cardiac radiofrequency ablation. Image processing utilizing various Matlab function can help identify different image intensities within the area of interest. The image intensities can be helpful to relate the pixel brightness to observe the information that the cardiac tissue is displaying. Thus, allowing clinical studies to identify ablated scar tissue based on the tissue properties through pixels.

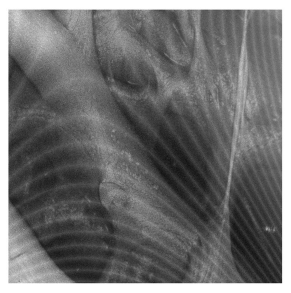
METHODS

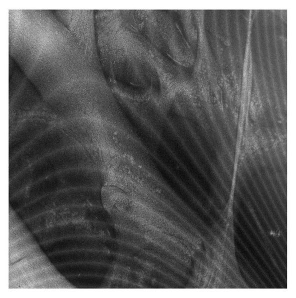
- Post-mortem, de-identified human hearts obtained from the National Disease Research Interchange (NDRI) were imaged fresh (within 24-48 hours after surgery).
- In the lab, we used the Thorlab Telesto I OCT system, to image the endocardium of the ventricle. The OCT system provides high-resolution visualization with a source centered at a wavelength of 1325 nm and a bandwidth of 150 nm. The axial resolution of the system is 6.5 um and the lateral resolution is 15 um. The imaging depth is 2.51 mm in air. [4]
- First, we extracted each OCT volume. After extraction, each volume was individually processed to obtain the maximum, standard deviation, sum, and variance projections.
- Producing projections can clarify what is going on with the tissue sample in each image.
- We calculated the mean, variance, skewness, and kurtosis on the histograms of the pixel intensities of the different projections. A histogram is helpful because it displays the distribution of the pixels.

Sample 1 Tissue:

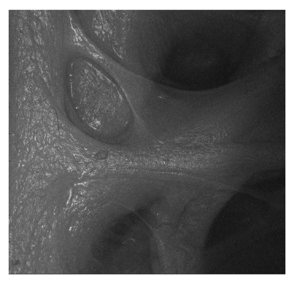

Sum Projection

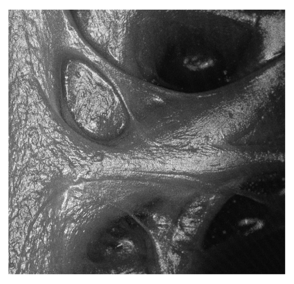

Maximum Projection

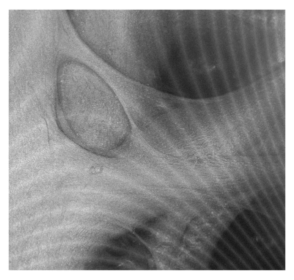

Standard Deviation

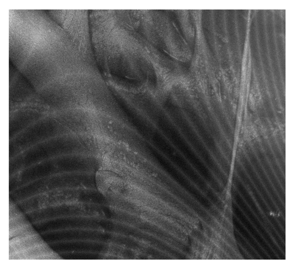

Variance Projection

Sample 2 Tissue:

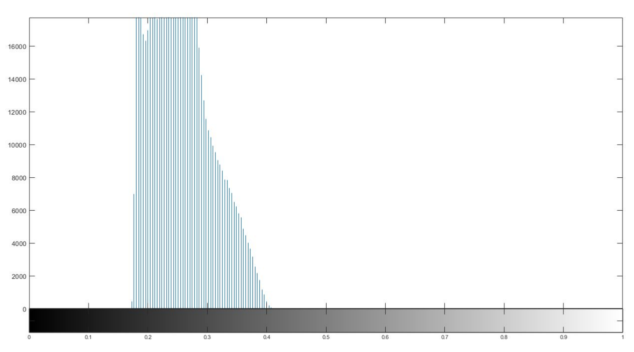

Sum Projection

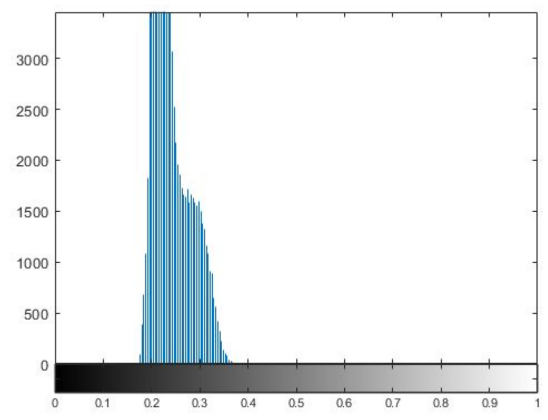

Maximum Projection


Standard Deviation


Variance Projection

Sample Histograms:


Histogram of the maximum projection .[Sample 1]



Histogram of the maximum projection .[Sample 2]

$$\mu = \frac{1}{N}\sum_{i=1}^{N} A_i.$$
Mean

$$V = \frac{1}{N-1}\sum_{i=1}^{N} |A_i - \mu|^2$$
Variance

$$s_0 = \frac{\sqrt{n(n-1)}}{n-2} s_1.$$
Skewness

$$k_0 = \frac{n-1}{(n-2)(n-3)}((n+1)k_1 - 3(n-1)) + 3.$$
Kurtosis

RESULTS

Sample 1

	Mean	Variance	Skewness	Kurtosis
Standard Deviation Projection	0.0338	1.0274	0.3718	3.7175
Variance Projection	0.0012	4.053	0.6031	3.544
Maximum Projection	0.2385	0.014	0.9765	3.1212

Sample 2

	Mean	Variance	Skewness	Kurtosis
Standard Deviation Projection	0.0367	1.1953	-0.1719	2.1833
Variance Projection	0.0012	9.9097	0.0278	2.1433
Maximum Projection	0.2508	0.0026	0.4701	2.5697

DISCUSSION

Image intensity is vital when sampling tissue because it determines whether the disease is absent or present when examining scans. Clinical approaches can also determine whether the disease present has progressed or not. A raw image may not tell the same story as a processed image. The ability to differentiate between diseased cardiac tissue and normal cardiac tissue changes throughout various image properties. When examining the skewness values from the standard deviation projection, we find that Sample 1 has of 0.3718 while Sample 2 has a skewness of -0.1719. This analysis indicates that the image intensity distribution is evenly distributed throughout the image. Sample 2 is slightly less than Sample 1 but is close to zero, meaning each image's pixels are approximate to even distribution. There are distortions within the standard deviation projection which can arise problems, such as a false evaluation when viewing the images.

FUTURE WORK

Prospective work will focus on making OCT scanning more practical for clinical applications. OCT imaging can transform the way that heart diseases are viewed and can create new methods of treatment. To better understand scans, a contrast enhancement algorithm could be created to precisely intensify images based on the properties based on the image. Work could be completed to create an algorithm to eliminate noise and distortion within the pictures.

REFERENCES

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