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Segmentation & Mechanical Characterization of Atherosclerotic Plaques

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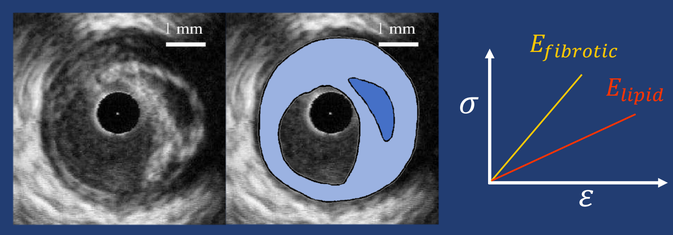
INTRODUCTION

Cardiovascular diseases are the leading cause of death worldwide. Atherosclerosis is one of the most common triggers of coronary events. This pathology consists of the deposition of lipids inside the coronary walls. If the fibrotic tissue surrounding the lipid core ruptures, the patient will suffer an obstruction of the artery → Early diagnosis of vulnerable plaques is important.

OBJECTIVES

- Tissues segmentation.
- Geometrical measures.
- Estimation of mechanical properties.



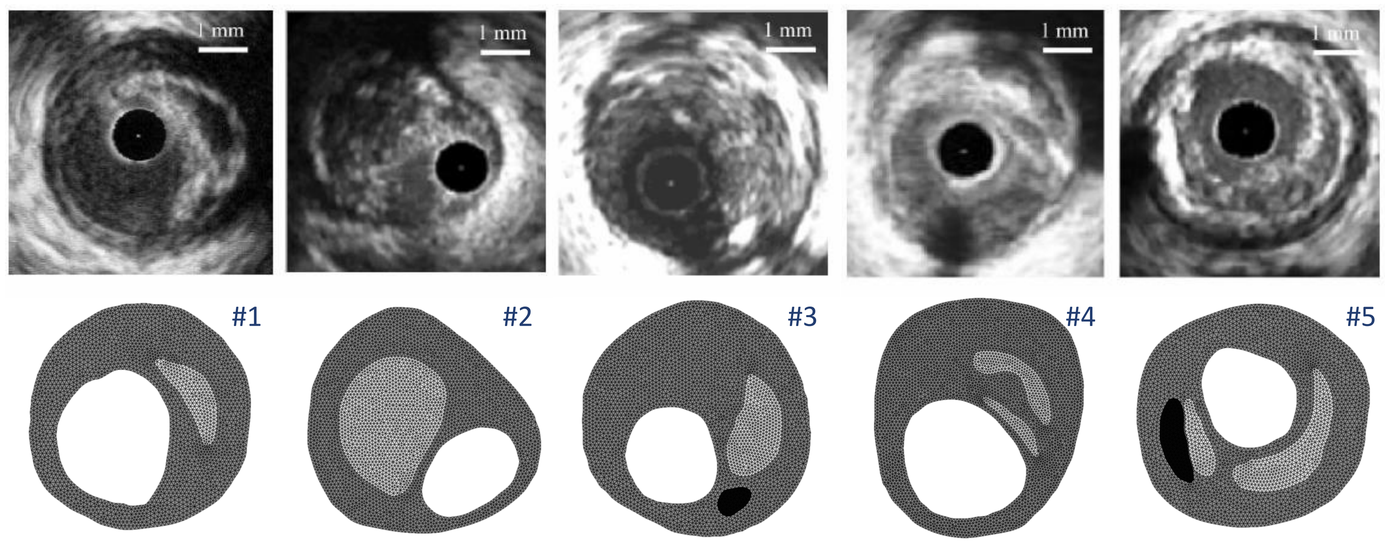
MATERIALS & METHODS

1st Simulating IVUS Data: 5 real IVUS geometries were considered for modeling 2D finite element models (1). The zero pressure geometry was recovered with a pull-back algorithm (2). The materials were modeled as Neo Hookean.

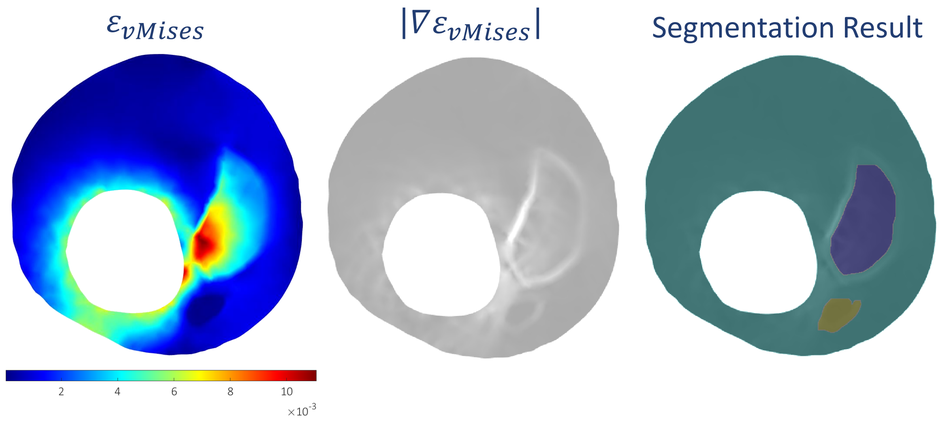
2nd Segmentation: the process is based on the representation of strain variables. The modulus of the gradient of the strains (e.g. $|\nabla \varepsilon_{vMises}|$) marks the tissue contours. This is the input for our Watershed-Gradient Vector Flow segmentation process.

3rd Estimation of Mechanical Properties: The linear elastic properties of the tissues were achieved by an optimization process, comparing ε_{rr} in the segmented and IVUS models.

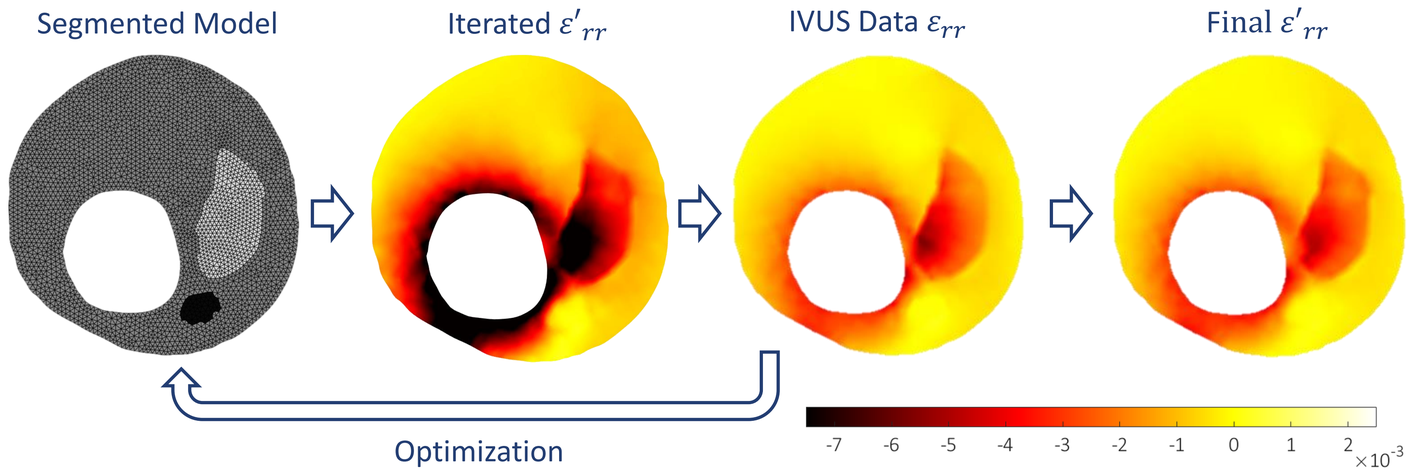
1st Simulating IVUS Data



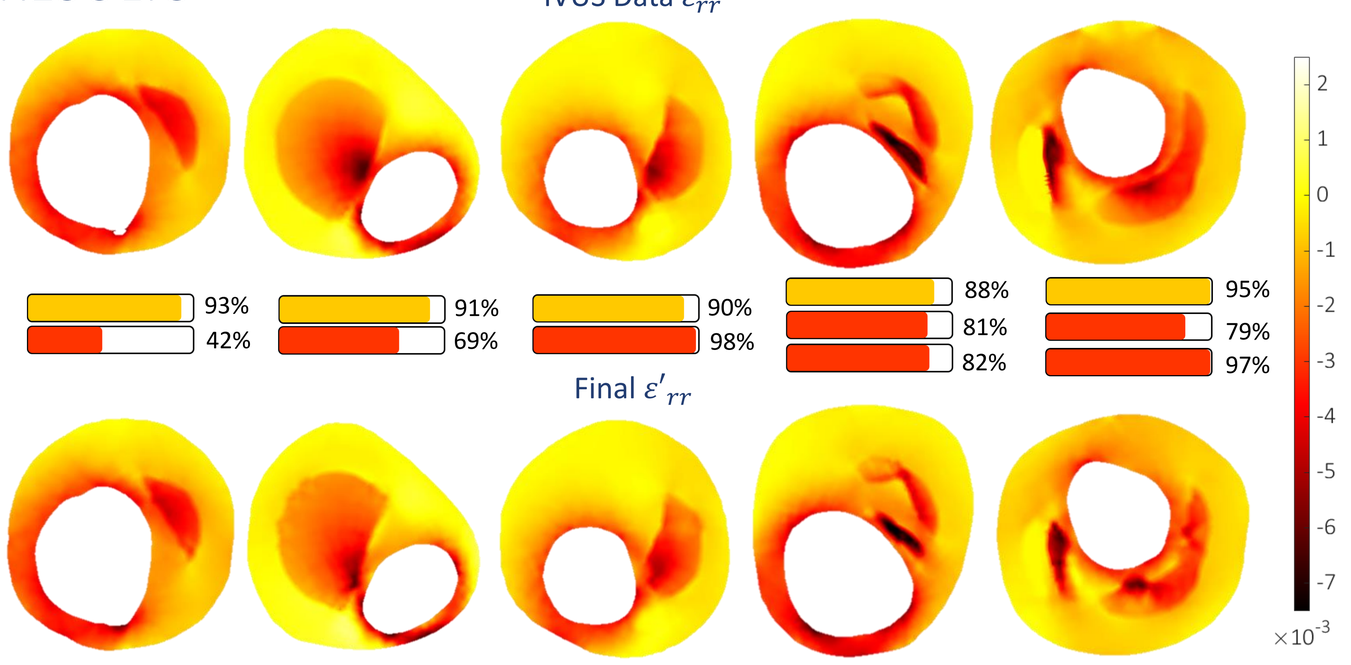
2nd Segmentation



3rd Estimation of Mechanical Properties



RESULTS



Plaque	Geometrical Features					
	Cap Thickness [µm]		Lipid Area [mm²]		Calc Area [mm²]	
	FEM	Segmented	FEM	Segmented	FEM	Segmented
#1	345	331	1.60	1.66	-	-
#2	200	199	5.58	5.71	-	-
#3	215.6	214.5	2	2.13	0.36	0.36
#4	139	67	0.5/1.2	0.49/1.3	-	-
#5	198	155.4	2.16/0.68	2.57/0.72	0.68	0.64

Successful estimation of Young modulus: Fibrotic Tissue Lipid Core(s)

CONCLUSIONS

- A novel methodology for automatic atherosclerotic plaque segmentation was presented, with promising results in real IVUS geometries.
- Geometrical measurements of areas and thicknesses related to vulnerability were taken with little error.
- The mechanical characterization of the material properties was achieved with good accuracy.

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