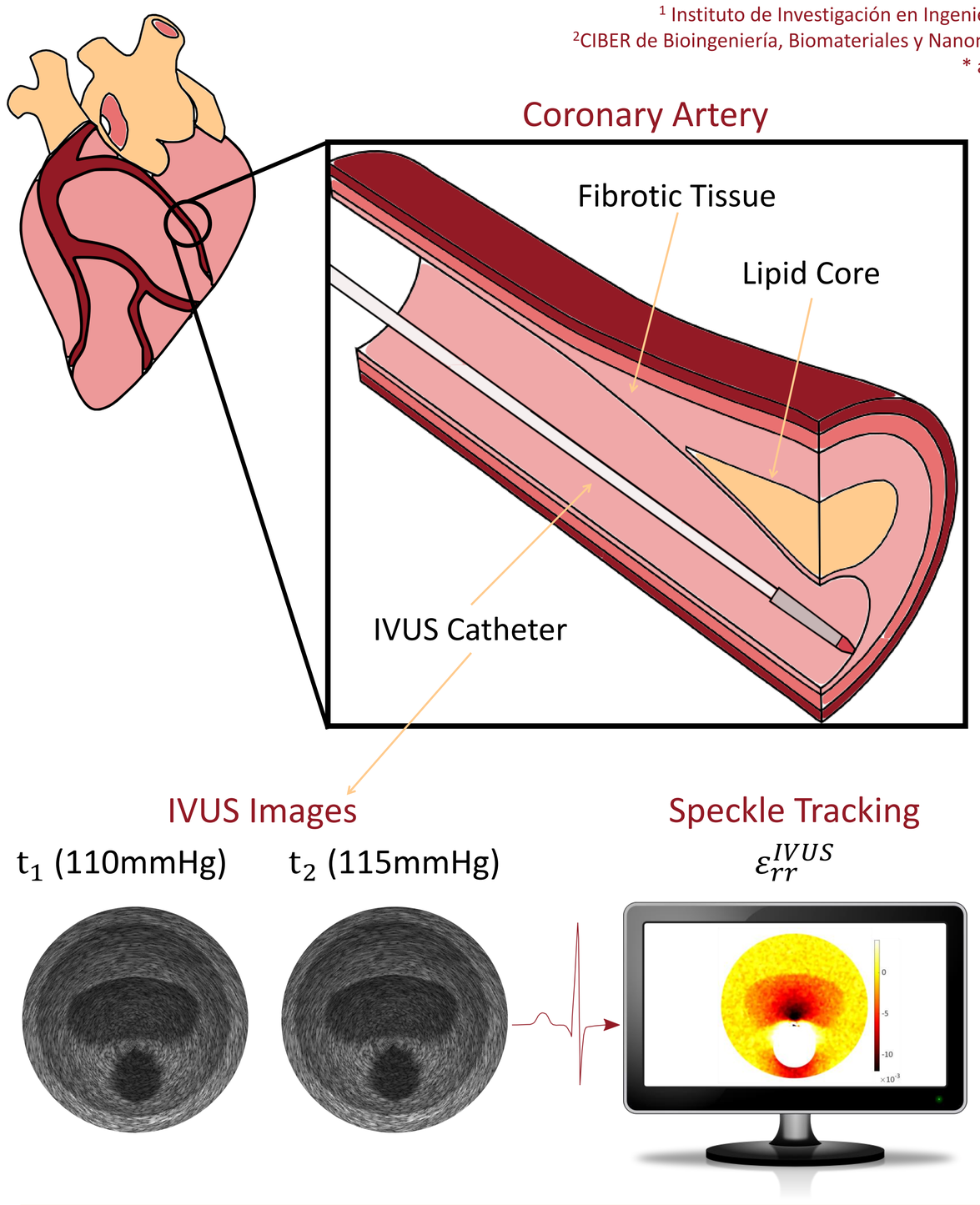
XII JORNADA DE JÓVENES INVESTIGADORES/AS DEL I3A

Instituto Universitario de Investigación de Ingeniería de Aragón
Universidad Zaragoza

Influence Of Hyperelastic Properties On The Assessment Of Atherosclerotic Plaque Vulnerability By Inverse Analysis

Álvaro Tomás Latorre[1*], Miguel Ángel Martínez[1,2], Estefanía Peña[1,2]
[1] Instituto de Investigación en Ingeniería de Aragón (I3A) Universidad de Zaragoza, Spain.
[2]CIBER de Bioingeniería, Biomateriales y Nanomedicina (CIBER-BBN), Aragon Health Sciences Institute, Spain
* alatorr@unizar.es



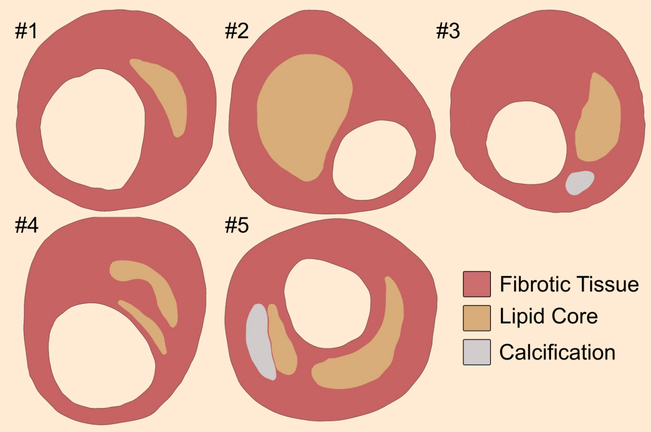
INTRODUCTION

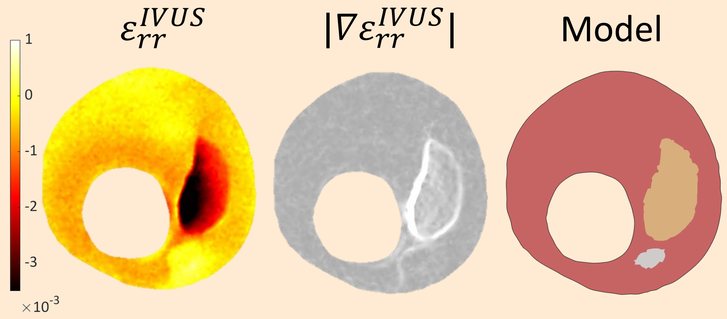
Atherosclerosis plaque rupture is one of the major causes of death worldwide. Therefore, the mechanical characterization of plaque tissues could estimate their vulnerability. This work presents a theoretical methodology to obtain the plaque tissues' hyperelastic behavior and its unpressurized geometry from IVUS images.

MATERIALS & METHODS

1st Simulating IVUS Data

Coronary arteries were simulated using finite element models with real patient geometries. IVUS data were mimicked by adding a 20dB signal-to-noise ratio over the strain fields.



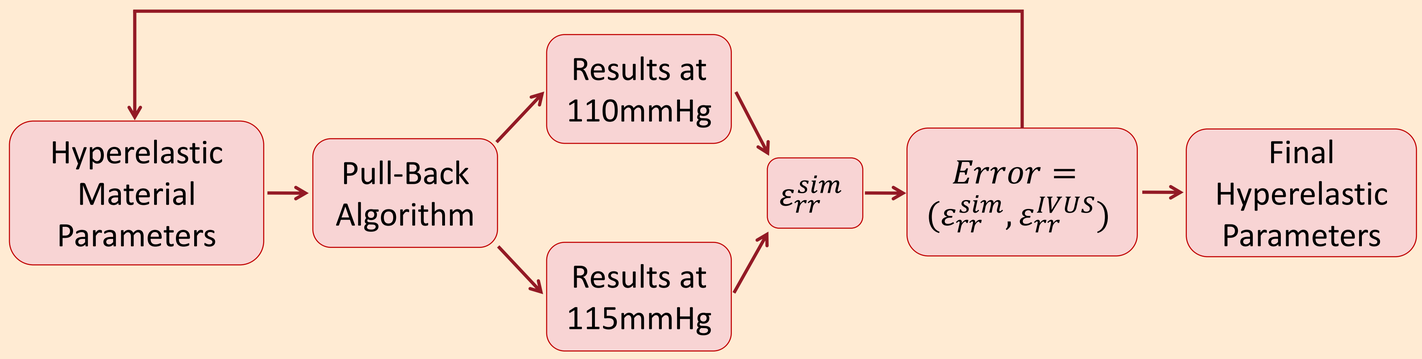


2nd Segmentation

Image segmentation was performed through a watershed process over the representation of the strain variable $|\nabla\varepsilon_{rr}^{sim}|$ [1].

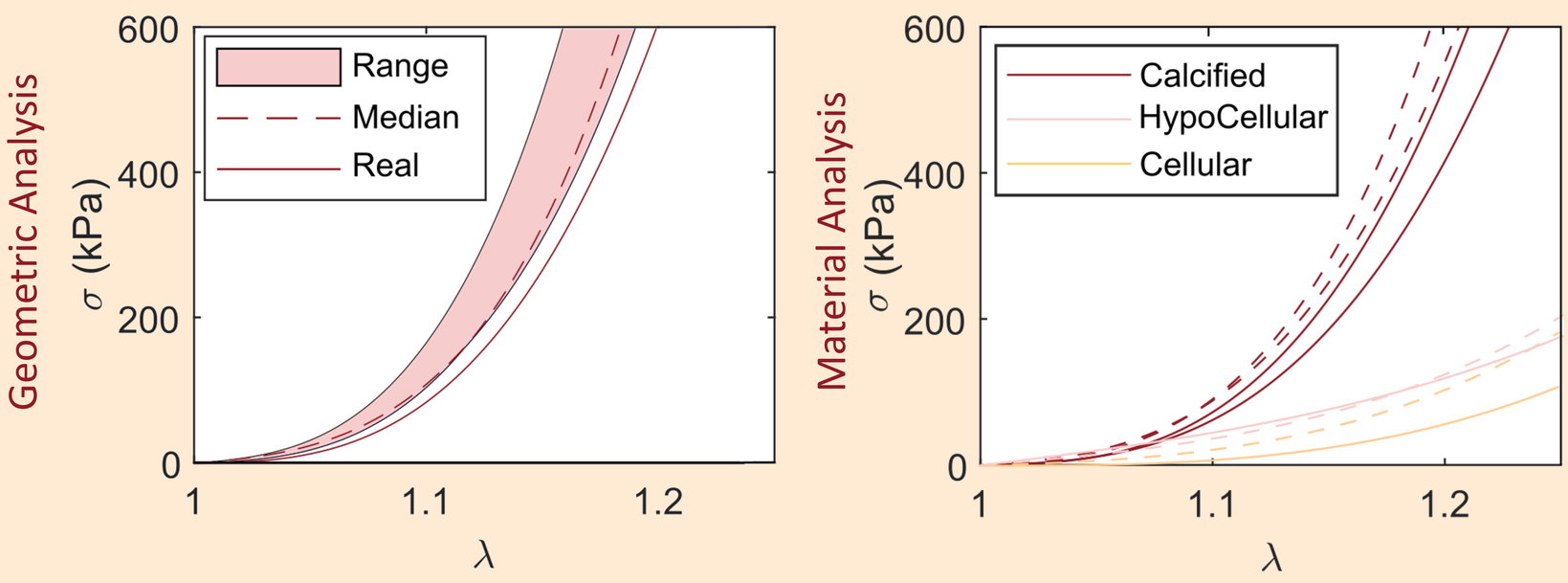
3rd Estimation of Mechanical Properties:

During each iteration, the optimization algorithm selected the material parameters and generated a finite element model. Then, a Pull-Back algorithm estimated the unpressurized geometry [2]. Finally, the resulting radial strain between 110-115mmHg was compared with the IVUS strains.



RESULTS

- Fibrotic tissue was characterized by a hyperelastic behavior described by Gasser's equation [3].
- Behavior curves (σ-λ) were analyzed for the fibrotic tissues of five different geometries and four different materials.
- After the optimization, zero-pressure geometry of the plaque was recovered.



CONCLUSIONS

- A novel methodology was developed to characterize the hyperelastic properties of the plaque tissues. It also estimated the unpressurized geometry of the plaque.
- The methodology obtained promising results with real patient geometries and different fibrotic tissue behaviors.
- The methodology could provide an estimation of the stress on the arterial wall, giving an important tool for analyzing the mechanical response.

BIBLIOGRAPHY

1. LATORRE, Á.T., et al. Atherosclerotic Plaque Segmentation Based on Strain Gradients: A Theoretical Framework. *Mathematics*. 2022, 10(21), pp. 4020-4040. doi: 10.3390/math10214020
2. RAGHAVAN, M.L., MA, B., and FILLINGER, M. F. Non-invasive determination of zero-pressure geometry of arterial aneurysms. *Ann Biomed Eng*. 2006, 34(9), pp. 1414-1419. doi:10.1007/s10439-006-9115-7
3. GASSER, T.C., OGDEN, R.W. and HOLZAPFEL, G.A. Hyperelastic modelling of arterial layers with distributed collagen fibre orientations. *JR Soc Interface.* 2006, 3(6), pp. 15-35. doi: 10.1098/rsif.2005.0073

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