XI JORNADA DE JÓVENES INVESTIGADORES DEL I3A

Artificial Neural Networks In The Prediction Of Atheroma Plaque Vulnerability

Ricardo Caballero[1], Miguel Ángel MartÍnez[1], Estefanía Peña[1,2]

[1]Applied Mechanics and Bioengineering (AMB), Aragón Institute of Engineering Research (I3A)

[2]Biomedical Research Networking Center in Bioengineering, Biomaterials and Nanomedicine (CIBER-BNN)

Instituto Universitario de Investigación en Ingeniería de Aragón Universidad Zaragoza

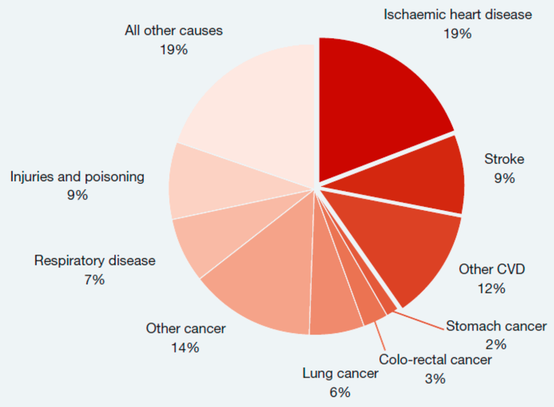
Universidad Zaragoza 1542

Introduction

Atherosclerosis is the accumulation of foam cells due to an excess of low-density-lipoproteins going across the endothelium.

The greatest risk of atherosclerosis occurs when the atheroma plaque is **vulnerable**.

If an atheroma plaque breaks, it can trigger either a myocardial infarction or stroke.

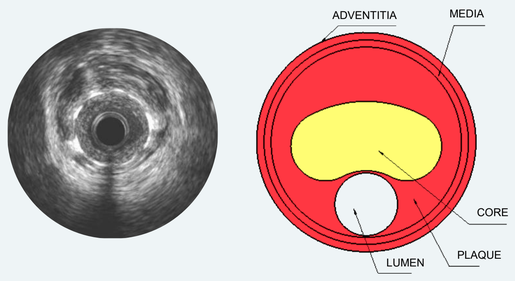


- **Deaths from CVD: more than 17.9 million people**
- **Economic impact: 169 billions €**

Materials and Methods

Model

- An idealized finite element model is developed from **IVUS images**[1]
- Different material properties were assigned to each part of the model



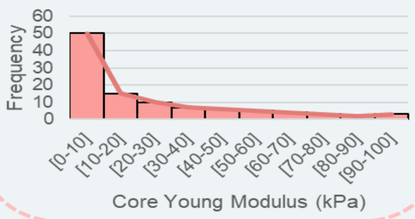
Core and Plaque

Neo-Hook

$$W = C_1(I_1 - 3) + D_1(J - 1)^2$$

$$C_1 = \frac{E}{6}$$

E Ranges For Coronary Artery	
Ecore (kPa)	**Eplaque (kPa)**
1 – 100	390 – 1200



Media and Adventitia

Gasser et al. (2006)

$$\Psi = \frac{1}{D}(J-1)^2 + \mu(I_1 - 3) + \frac{k_1}{2k_2}\sum_{i=4,6}\exp\left(k_2\left(k(I_1-3)+(I_1-3k)(I_i-1)\right)^2\right) - 1$$

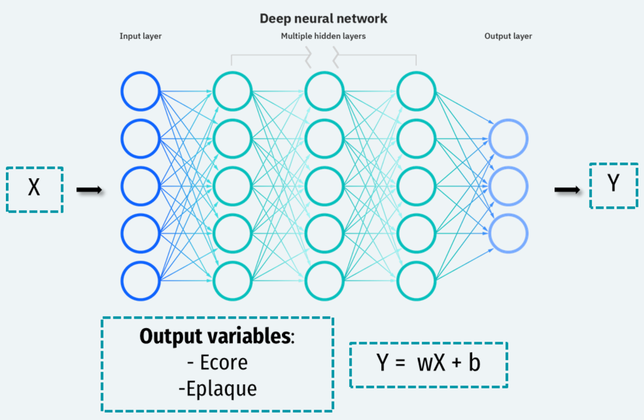
Material Parameters				
C1 (kPa)	**D (kPa^{-1})**	**k1 (kPa)**	**k2**	**k**
0.7	0	206.16	58.55	0.29
4.22	0	547.67	568.01	0.26

Statistical Analysis

- A **statistical analysis** was performed to determine which variables best explained the model and have a better criterion to select the inputs of the ANN

Candidate Variables		
ε_1	ε_2	ε_{core}
ε_{cap}	ε_{theta}	SR (%)

Artificial Neural Network



Output variables:
- Ecore
-Eplaque

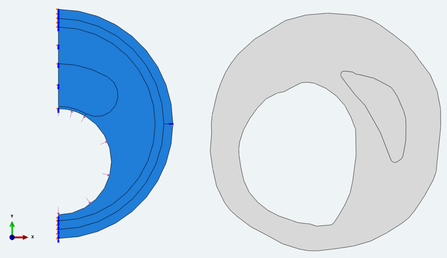
$Y = wX + b$

Min.-Max. Scaler

$$X_{scaled} = \frac{X - X_{min}}{X_{max} - X_{min}}$$

Validation

Real Geometries	
Geometry	e_{cap}
#1	65 μm
#2	250 μm
#3	480 μm



Idealized geometry vs real geometry

Results

Statistical Analysis

- Descriptive analysis

- Multivariate regression analysis

	Coef	P-value
Constant	2540	$< 10^{-3}$
SR (%)	-53.62	$< 10^{-3}$
$\varepsilon_{core-cuad}$	-2978	$< 10^{-3}$
$\varepsilon_{cap-cuad}$	4109	$< 10^{-3}$
R-squared	92.80 %	

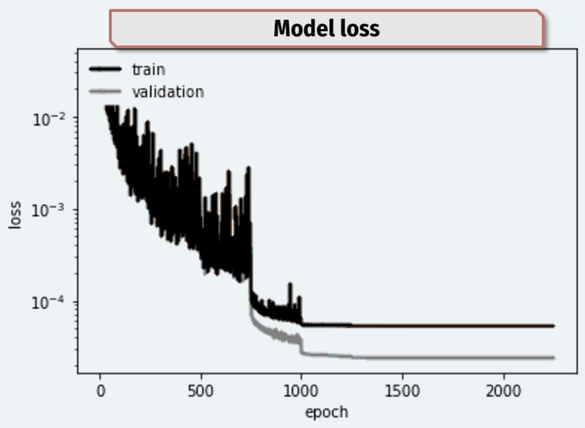
Artificial Neural Network

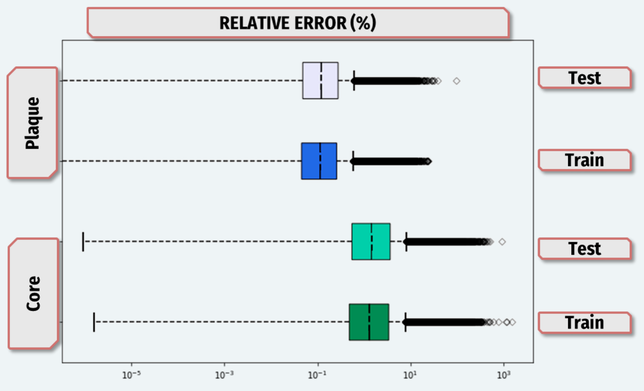
Architecture

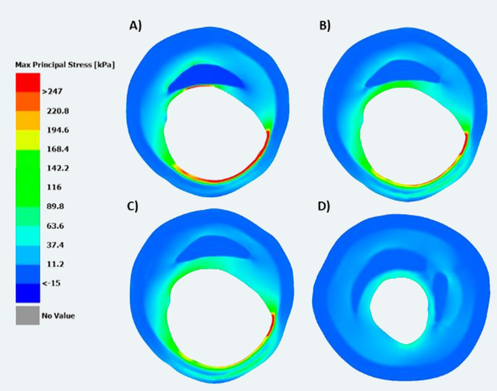
- **11 hidden layers**
- **4.369.562 parameters**

Loss function

$$MSE = \frac{1}{n}\sum(y_i - \tilde{y}_i)^2$$







	Prediction			Real		
Geom	**Ecore (kPa)**	**Eplaque (kPa)**	**Max. Principal Stress (kPa)**	**Ecore (kPa)**	**Eplaque (kPa)**	**Max. Principal Stress (kPa)**
A	4.54	1080.17	296.20	11.1	601	286.79
B	3.42	659.69	142.85	11.1	601	143.47
C	0.685	587.90	96.86	11.1	601	96.02
D	19.8	1200	87.7	11.1	600	81.4

Conclusions

- **Acceptable errors in the estimation of Young Modulus do not affect vulnerability prediction**
- **It is possible to develop an ANN to predict mechanical properties of atherosclerotic coronary artery**
- **A future improvement of this work could be to rely on a higher number of IVUS, developing 3D geometries and including an anisotropic constitutive model of the material**

References

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[2] HOLZAPFEL GA, GASSER TC and OGDEN RW. A new constitutive framework for arterial wall mechanics and a comparative study of material models. 6, s.l. *: Journal of Elasticity*, 61(1):1-48, 2000.

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rcaballero@unizar.es