A Framework for Human Coronary Plaque Vulnerability Assessment Based on Patient-Specific Intravascular Ultrasound (IVUS) Imaging, Computational Modeling and Biaxial Artery Material Properties

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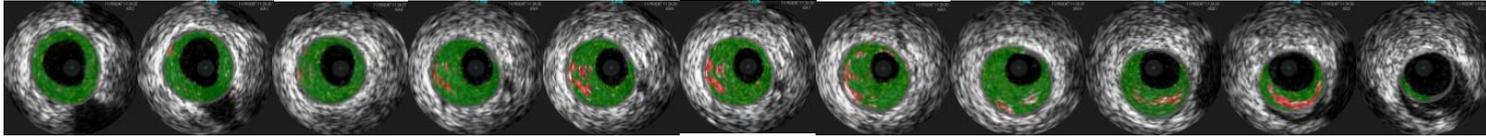[4] Radiation Oncology, Washington University School of Medicine, Saint Louis, MO 63110

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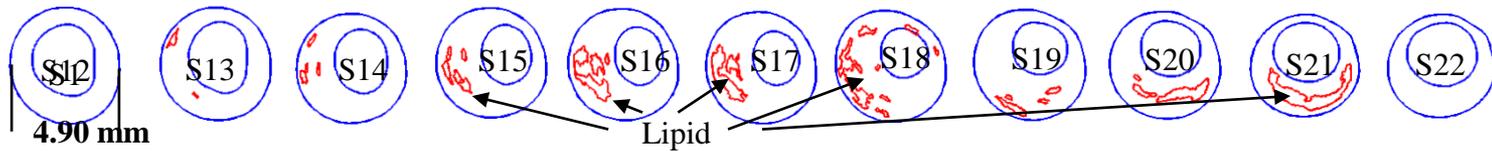
Acknowledgement

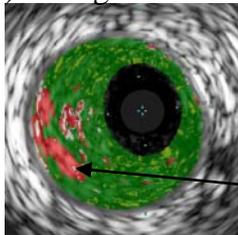# Factors Affecting Model Predictions for Coronary Plaque Assessment: Morphology, Material, Pressure, Cardiac Motion

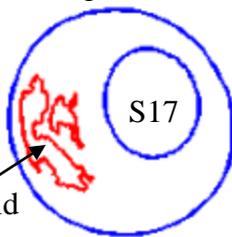(a) Coronary IVUS images from a patient, selected IVUS slices from a 44-slice set

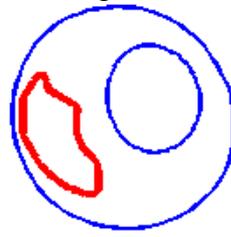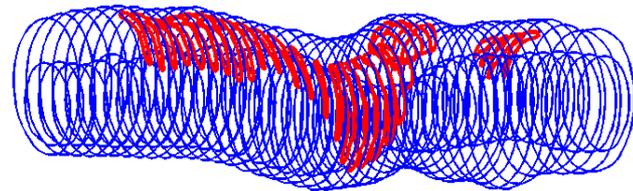

(b) Contour plots of selected IVUS slices

S12 S13 S14 S15 S16 S17 S18 S19 S20 S21 S22

4.90 mm

Lipid

(c) Enlarged view

Lipid

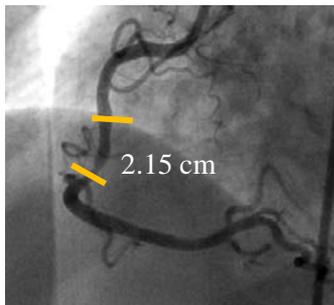(e) Enlarged contour

S17

Lipid
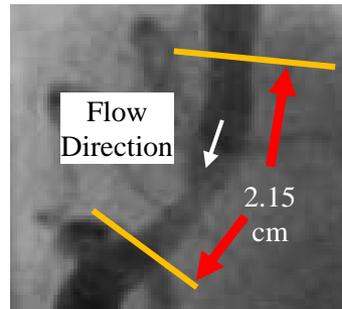
(e) Enlarged contour

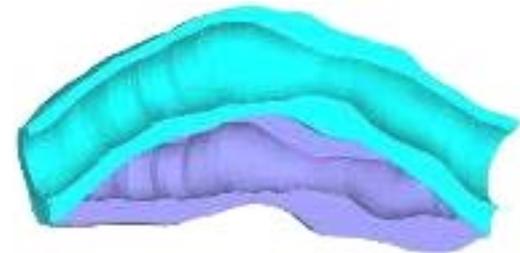(f) 3D geometry showing 44 slices and lipid core locations

(g) Angiographic image showing location of the imaged coronary segment.

2.15 cm

(b) Enlarged view of the segment and flow direction.
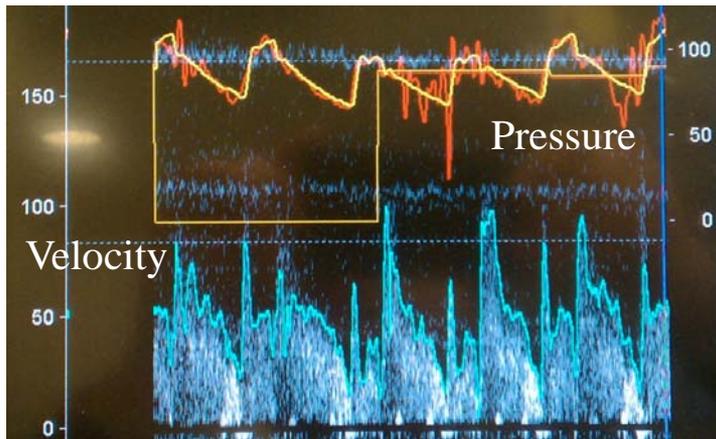

Flow Direction

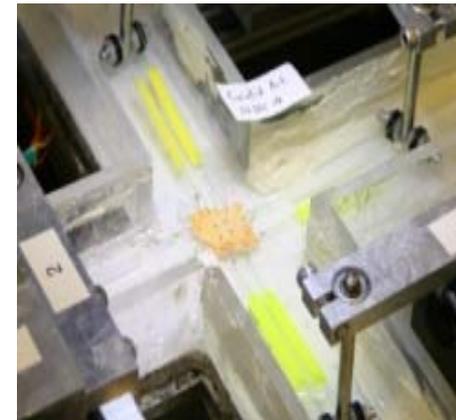2.15 cm

(c) Illustration of coronary vessel bending.

On-Site Pressure and Flow Velocity Biaxial Testing of Coronary Material Properties
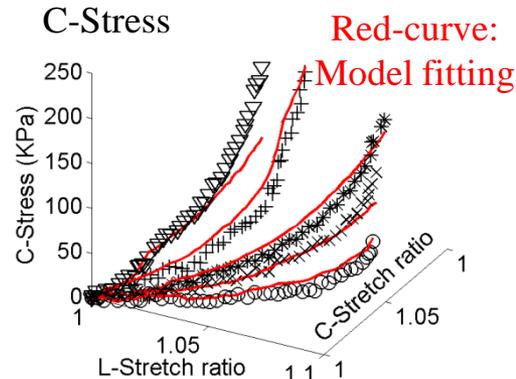
(a) IVUS Measured On-Site Blood Pressure and Velocity

Pressure

Velocity

(b) Tissue sample mounted for biaxial test

(c) Measured Anisotropic Stress-Stretch Data from a Human Coronary Sample

L-Stress

Red-curve: Model fitting

C-Stress

Red-curve: Model fitting
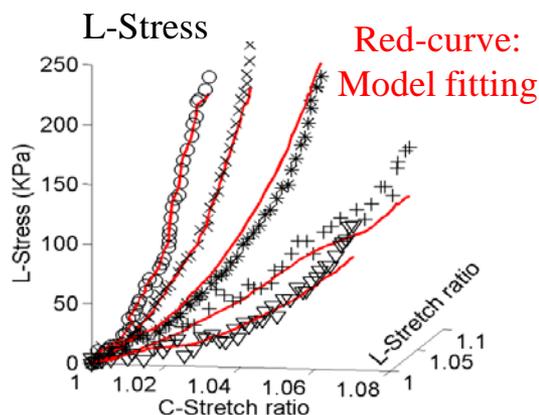
The biaxial testing results showing 3D plots of stress-stretch data from a human coronary sample fit by the anisotropic Mooney-Rivlin model. Markers for protocols with 5 axial:circumferential force ratios: *: 250-250; X : 250-170; O:250-125; +:170-250; V:125-250.

Impact of Material Properties, Bending and Stretch on Stress/Strain Predictions
Impact on Multi-Scale Model and Cell Behaviors

(a) M1, Pin=86 mmHg, No Bending — Max=46.3 KPa

(b) M2, Pin=86 mmHg, No Bending — Max=75.3 KPa

(c) M3, Pin=86 mmHg, κ=0.97 cm^{-1} — Max=104.7 KPa

(d) M4, Pin=86 mmHg, κ=0.97 cm^{-1} — Max=205.9 KPa

Min — Universal Scale — Max
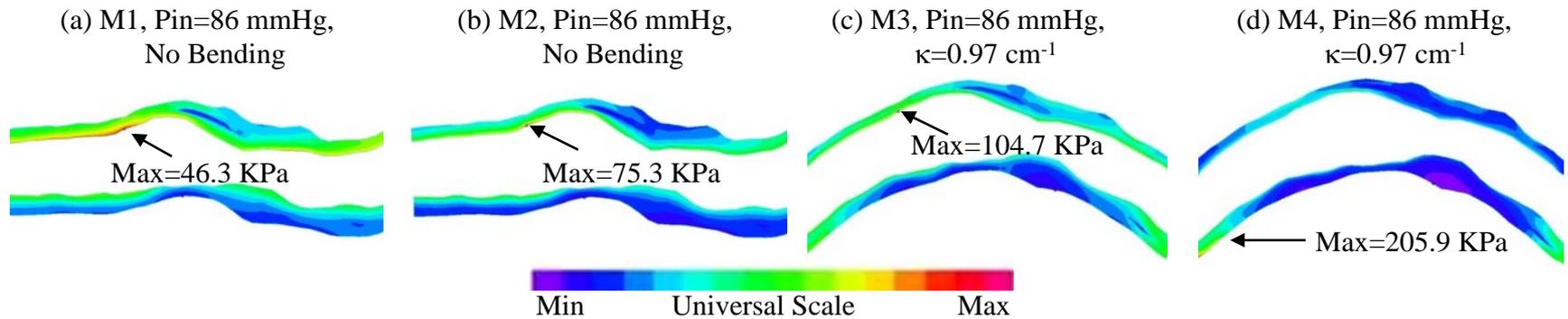
Model	Max Stress-P_1 on Cut Surface				Max Strain-P_1 on Cut Surface			
	κ=0.97 Pin=86	κ=0.76 Pin=130	κ=0.39 Pin=101	κ=0.88 Pin=70	**κ=0.97 Pin=86**	κ=0.76 Pin=130	κ=0.39 Pin=101	κ=0.88 Pin=70
M1, iso, no-bending	**46.3 (100%)**	86.0 (100%)	58.5 (100%)	34.9 (100%)	**0.147 (100%)**	0.204 (100%)	0.168 (100%)	0.124 (100%)
M2, aniso, no bending	**75.3 (163%)**	153.8 (179%)	98.9 (169%)	53.2 (152%)	**0.300 (204%)**	0.395 (194%)	0.339 (202%)	0.252 (203%)
M3, aniso, with bend	**104.7 (226%)**	205.6 (239%)	122.5 (209%)	75.4 (216%)	**0.556 (378%)**	0.483 (237%)	0.373 (222%)	0.509 (410%)
M4, aniso,Bend, 10% axial stretch	**205.9 (445%)**	222.6 (259%)	146.4 (250%)	142.5 (408%)	**0.722 (491%)**	0.602 (295%)	0.447 (266%)	0.643 (519%)