FOCUS ON IMAGING

In Application

Optimization of OCT and DVC Techniques to Measure Strain Fields in Aortic Tissues

Center for Biomedical and Healthcare Engineering, Mines Saint-Etienne I ENSM-SE, France

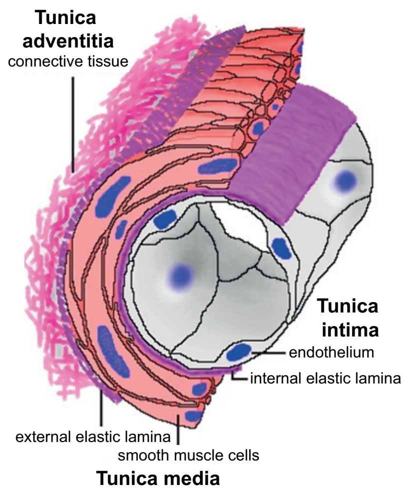
Introduction

In order to develop safe optical-clearing methods for possible in vivo applications, there is a need to investigate the mechanical response of biological tissues immersed in tissue clearing agents. The tissues behave differently if immersed in phosphate buffered saline (PBS) and in clearing agent, such as propylene glycol (PG), but the differences have been poorly investigated so far.

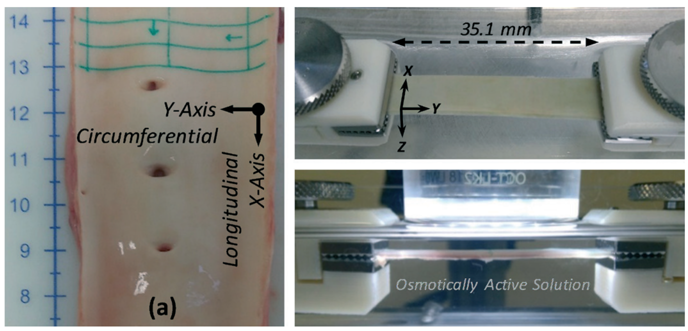
Optical coherence tomography (OCT) is an imaging technique to visualize tissue structures at a micrometric scale. It has been used to detect and characterize microscale defects or changes in soft and hard human tissues.

Here in an aorta, the mechanical behavior is expected to be anisotropic, because of the different fibers (elastin and collagen), and the disposition of these through the three different layers (intima, media and adventitia). Hence, the strain gradients can fluctuate significantly through the thickness of the tissue. In this context, superficial measurements by Digital Image Correlation (DIC) on the surface of the sample is not enough and a 3D full-field deformation measurement can only be provided by Digital Volume Correlation (DVC), using 3D cross-sectional images with sufficient contrasts. Fu et al. (2013) applied OCT and DVC methods on silicone gels but this is the first OCT/DVC approach that we know of on aortic tissue. The difficulties in this case are its limited penetration depth (500 µm) and poor image contrast. Therefore OCT were measured in different media with different refractive indices in order to quantify the optical effect and the mechanical changes in using different liquids.

Experimental Setup



Porcine aortic tissues are immersed in different media, including water and propylene glycol (PG as clearing agent) and subjected to stress-relaxation uniaxial tensile test. Displacement and strain fields are measured across the whole thickness of the porcine aortic wall (2 mm).



LaVisionUK Ltd
2 Minton Place / Victoria Road
Bicester, Oxon / OX26 6QB / United Kingdom
E-Mail: sales@lavision.com / www.lavisionuk.com
Phone: +44-(0)-870-997-6532 / Fax: +44-(0)-870-762-6252

LaVision GmbH
Anna-Vandenhoeck-Ring 19
D-37081 Göttingen / Germany
E-Mail: info@lavision.com / www.lavision.com
Tel. +49-(0)551-9004-0 / Fax +49-(0)551-9004-100

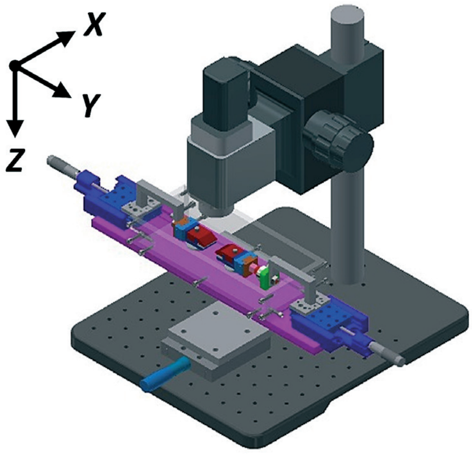
LaVision Inc.
211 W. Michigan Ave. / Suite 100
Ypsilanti, MI 48197 / USA
E-Mail: sales@lavisioninc.com / www.lavisioninc.com
Phone: (734) 485 - 0913 / Fax: (240) 465 - 4306

Optimization of OCT and DVC Techniques to Measure Strain Fields in Aortic Tissues

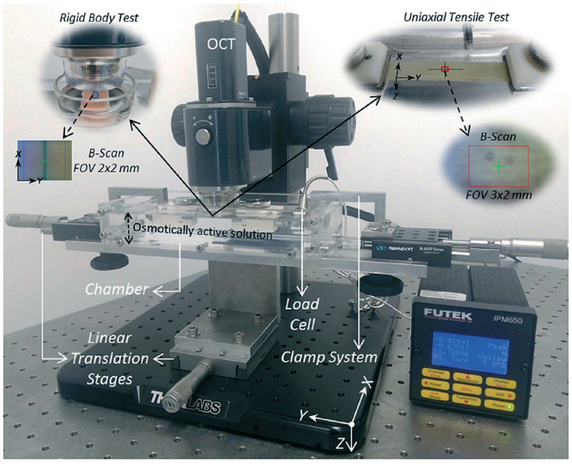
Optimization of OCT and DVC Techniques to Measure Strain Fields in Aortic Tissues

Center for Biomedical and Healthcare Engineering, Mines Saint-Etienne I ENSM-SE, France

The OCT system was a Thorlabs OCT- TEL220C1 with a lateral resolution 7 μm, imaging depth 2.6 mm (in water), axial resolution 4.2 μm in water and 5.5 μm in air. (The propylene glycol refractive index is 1.432).



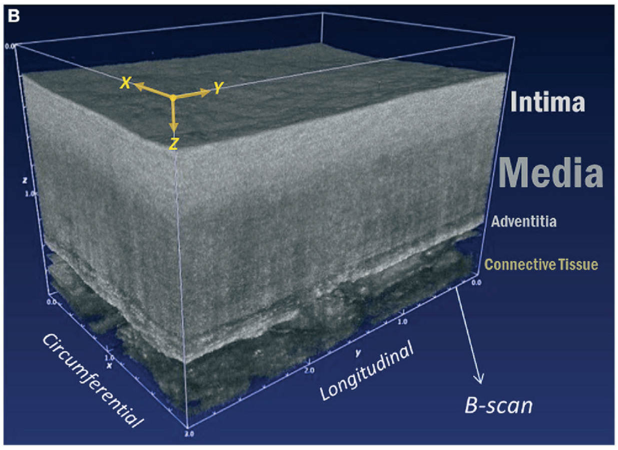
Dimensions investigated: pixel size of 2.4 to 6 microns. Total size from 300 to 700 voxels. First, rigid body translations (RB) were performed to optimize the OCT and DVC parameters to use.
Then uniaxial tensile tests (UT) were performed with a FOV of 2 x 3 x 2.3 mm (333 x 500 x 940 pixels and pixel size 6 microns).

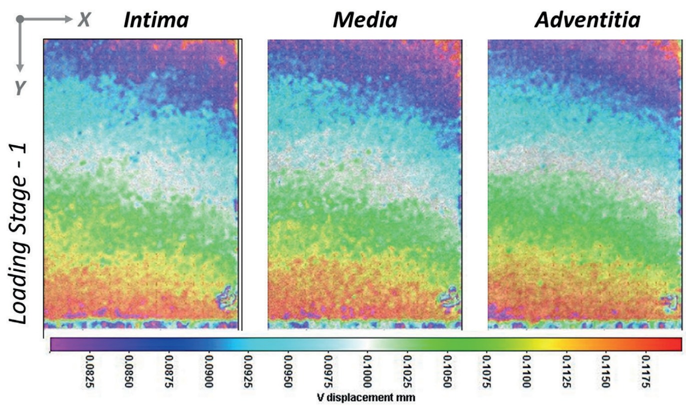


Results

The main effects of propylene glycol can be quantified: stiffening of the tensile response, compared to the immersion in phosphate buffered saline (PBS), reversibility of this effect, and reduction in the Poisson's effect. The OCT-DVC combined measurements also reveal heterogeneities of this effect among the different layers of the aorta. The next step, beside using these results to fine-tune numerical models, would be to study fracture and damage mechanisms, such as involved in aneurism ruptures.

For further details the reader is referred to Acosta Santamaría, Víctor & Flechas García, María & Molimard, Jérôme & Avril, Stéphane. (2018). Three-Dimensional Full-Field Strain Measurements across a Whole Porcine Aorta Subjected to Tensile Loading Using Optical Coherence Tomography–Digital Volume Correlation. Frontiers in Mechanical Engineering. 4. 10.3389/fmech.2018.00003.





05/19

LaVisionUK Ltd
2 Minton Place / Victoria Road
Bicester, Oxon / OX26 6QB / United Kingdom
E-Mail: sales@lavision.com / www.lavisionuk.com
Phone: +44-(0)-870-997-6532 / Fax: +44-(0)-870-762-6252

LaVision GmbH
Anna-Vandenhoeck-Ring 19
D-37081 Göttingen / Germany
E-Mail: info@lavision.com / www.lavision.com
Tel. +49-(0)551-9004-0 / Fax +49-(0)551-9004-100

LaVision Inc.
211 W. Michigan Ave. / Suite 100
Ypsilanti, MI 48197 / USA
E-Mail: sales@lavisioninc.com / www.lavisioninc.com
Phone: (734) 485 - 0913 / Fax: (240) 465 - 4306