

## Method and system for vascular elastography: Non-invasive vascular elastography (NIVE and MicroNIVE).

Reference: VAL-358-CHUM; VAL-359-CHUM

**Keywords:** Non-invasive vascular elastography (NIVE), vessel wall elastic properties, atherosclerosis, vascular pathologies, vulnerable plaque. Non-Invasive Micro-Vascular Elastography (MicroNIVE), small vessels, small animal imaging, ultrasound.

### Background

Elastography is defined as a biological tissue elasticity imaging technique. It can be used to study pathologies that affect the vascular wall mechanical properties. For example, it is known that the presence of atherosclerotic plaque stiffens the vascular wall, and that the heterogeneity of its composition may lead to plaque rupture and thrombosis. The rupture of an arterial aneurysm is another example that is related to the mechanical stability of the vessel wall.

Most of the conventional methods in elastography are one dimensional (1D) correlation-based estimators that only provide the map of the strain distribution in the direction of the ultrasound beam propagation (axial strain, or radial strain in endovascular elastography). This can set a potential limitation in non-invasive characterization of vessel walls with an extra-corporal ultrasound probe, since the ultrasound beam does not necessarily propagate in the same orientation as the tissue motion. Non-invasive vascular elastography (NIVE) was thus proposed to characterize the mechanical properties of arteries. This method was also adapted (MicroNIVE) to assess the mechanical properties of small superficial vessels in humans or vessels in experimental rodent animals.

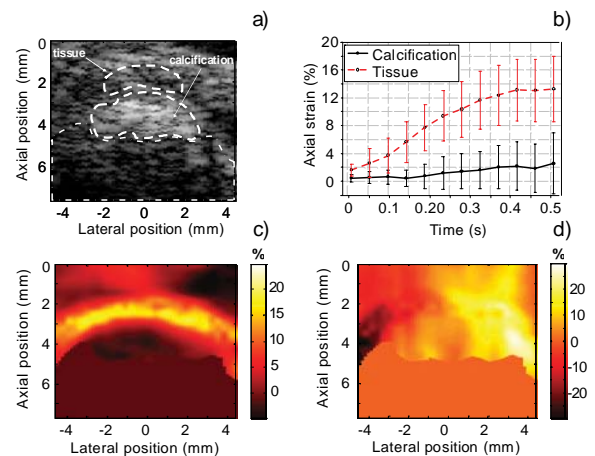
### Technology

The NIVE technology is introduced as an approach to non-invasively characterize the mechanical properties of arteries. A linear array ultrasound transducer is applied on the skin over the region of interest, and the arterial tissue is dilated by the normal cardiac pulsation. The elastogram, or elasticity image, is computed from the assessment of the vascular tissue motion. In the case where longitudinal images of the vessels are studied, the axial strain may be sufficient to characterize the wall in NIVE. On the other hand, to facilitate the visual interpretation of cross-sectional images, the Von Mises (VM) coefficient is proposed as a new characterization parameter since it is independent of the orientation (angle between the deformation

vector and the direction of propagation of ultrasound). The Lagrangian Speckle Model Estimator (LSME) is used to assess the wall motion because it provides the full two dimensional (2D) strain tensor necessary to compute the Von Mises coefficient. Additionally, the LSME can map the lateral strain, axial shear and lateral shear elastograms. Deformation parameters are estimated using an inversion algorithm.

MicroNIVE is an adaptation of the NIVE technology to high frequency ultrasound scans, which provide higher resolution images.

### Results

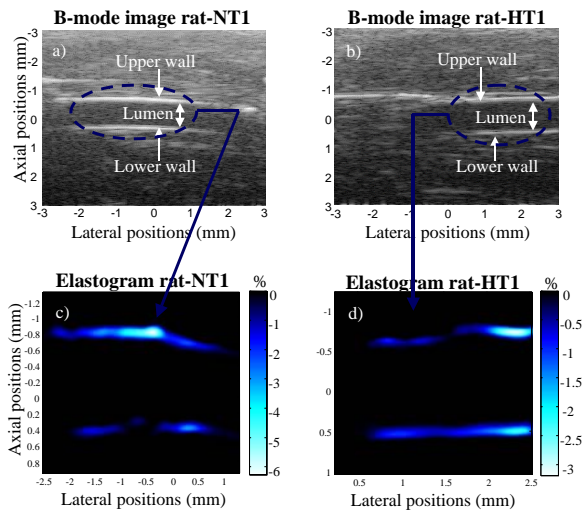


a) Internal carotid artery cross-sectional zoomed B-mode ultrasound image at 7 MHz of a 75-year-old male patient; b) axial strain averaged over 7 cardiac cycles for the vascular tissue and the calcified plaque segmented in a); c) cumulated axial strain elastogram between the end diastole and peak systole; d) cumulated axial shear elastogram also between the end diastole and peak systole.

The figure above shows *in vivo* results acquired from a patient with a calcified internal carotid plaque. Two regions of interest are defined in panel a) (a normal vascular wall tissue section and a region with calcium). As noted in panel b) (between early and peak systole), the calcified zone deformed much less than the tissue above it, as expected. The axial strain elastogram in panel c) shows a ratio of about 7% between both regions segmented in panel a). The calcified

plaque with low strains below 2% (brown mapping) is clearly delineated; it is surrounded by a softer ring (orange to yellow, strains between 5 - 20%) corresponding to the normal portion of the wall. The large deformation of the normal tissue (up to 20%) is believed to be due to the compression induced by the non-deformable calcified plaque. Because the LSME estimator provides the full strain tensor, it also allows the computation of shear elastograms. As noted in panel d), important heterogeneities in the shear patterns are observed at the shoulder between the calcified plaque and the surrounding tissue. This information may be pivotal because it may indicate sites prone to rupture, hemorrhage, inflammation and vessel thrombosis.

The next figure shows an example of *in vivo* MicroNIVE elastograms obtained by scanning the carotid artery of rats with a 40 MHz ultrasound probe. The carotid of the normotensive (NT) rat deforms twice (6%) than that of the rat with hypertension (HT) (3%), even if the systolic pressure was lower ( $87 \pm 12$  mmHg for NTs and  $158 \pm 16$  mmHg for HTs,  $n = 3$  in each group). This figure confirms the potential of this new technique for phenotyping genetic experimental rodent models.



a-b) Examples of B-mode ultrasound images of the common carotid artery acquired for a normotensive rat NT1 and a hypertensive rat HT1, respectively. c-d) Corresponding axial elastograms showing the strain distribution within the artery wall in percentages (color map) during diastole (vessel dilation producing negative strains).

## Applications

### NIVE :

- Non-invasive characterization of the atherosclerotic plaque vulnerability in vessels such as carotid and femoral arteries.
- Non-invasive characterization of the mechanical stability of arterial aneurysms.
- Prediction of arterial rupture sites in atherosclerosis and aneurysms.
- Assistance to the clinician in the diagnosis and follow-up of vascular pathologies.

### MicroNIVE :

- Non-invasive investigation of the impact of targeted genes in small vessels of genetically-engineered rodent models (rats and mice).
- Assessment of pathologies such as hypertension and atherosclerosis that affect the mechanical properties and structures of the vascular wall.

## Competitive Advantages

The calculation of the strain distribution in 2D offers a more accurate characterization of the atherosclerotic plaque vulnerability and aneurysmal rupture risk.

The shear parameters obtained with the LSME algorithm may provide some very important clinical insights relative to arterial mechanical stability.

Regarding cross-section data, hardening and softening misinterpretations of the deformation pattern can be counteracted with the use of the Von Mises parameter.

The characterization of small vessel mechanical properties with MicroNIVE could lead to significant new discoveries in functional genomics and pharmacogenetics.

## Patent Status

PCT application (PCT/CA2005/000162).

## Business Opportunity

Univalor is seeking an exclusive licensing agreement or contracts with a commercial partner.

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