MULTIPHYSICS MODELING TO SUPPORT THE DEVELOPMENT OF VASCULAR ULTRASOUND IMAGING

Abigail Swillens (1), Lasse Lovstakken (2), Joris Degroote (3), Jan Vierendeels(3), Patrick Segers (1)

1. IBiTech-bioMMeda, UGent; 2. Department of Circulation and Medical Imaging, NTNU, Trondheim; 3.FloHeaCom, UGent

Introduction
Ultrasound imaging is crucial for early detection of cardiovascular diseases. In particular, the carotid artery (in the neck) is often investigated, since this location is prone to atherosclerosis and provides blood to the brains. Hence, this is a good location to screen for a risk of stroke. Although ultrasound (US) is widely applied, current modalities show severe limitations regarding vascular flow and wall imaging, which may be (partially) revolted using more advanced image and signal processing techniques. When developing new imaging techniques, in-vivo research is less appropriate because it doesn’t allow to compare acquired US data with gold standard information on the underlying arterial properties (i.e. flow and wall mechanics). Therefore, we built a multiphysics model incorporating both the biomechanical problem as well as the US imaging. This allows generation of synthetic US data which can be directly linked to the underlying arterial mechanics.

Methods
To integrate the biomechanics with the US imaging physics, the multiphysics model links fluid-structure interaction (FSI) with US simulations. The realism of our model is illustrated by simulating duplex images (superposition of greyscale and 1D flow image) in a carotid artery.

1) FSI-simulations allow the coupled computation of blood flow and arterial wall mechanics. FSI-simulations were performed in a partitioned way, computing the flow and structural equations with a separate flow and structural solver. An in-house code Tango was used to couple the flow solver Fluent (Ansys) and the structural solver Abaqus (Simulia) [1].

A 3D carotid bifurcation model was reconstructed using CT data from an 83-year old volunteer, and embedded in a cylinder representing the surrounding tissue. At the in- and outlets of the model, physiologically realistic boundary conditions were imposed: i.e., a measured velocity profile at the inlet and a 35-65% outflow division at the outlets. A non-invasively measured pressure profile was further imposed. The vessel wall was modelled as a linear elastic material with Young’s modulus=250 kPa, density=1200 kg/m$^3$ and Poisson coeff.=0.49. For the surrounding tissue, a Young’s modulus=10kPa and Poisson coeff.=0.3 were chosen (complete overview of FSI-setup in fig.1A).

2) Field II-simulations: US-data were simulated using the Field II software created by Jensen et al [2], which allows modelling arbitrary US probes and realistic image scan sequencing. Field II models tissue as a distribution of point scatterers, whose position can be updated for each simulated US beam. By moving scatterers according to flow fields and wall deformations from FSI, imaging algorithms can be studied in complex conditions.

Results & Discussion

Fig.1A=FSI-model, B=simulated duplex image

Fig.1B shows realistic duplex images can be obtained from the multiphysics model: blood flow is visualized in 1D (in direction of US-beam) and bright reflections are present at tissue transitions. Direct comparison of the simulated images with the FSI ground truth, supports evaluation and development of applied imaging algorithms [3].

References