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Fluid Structure Interactions in Ascending Thoracic Aortic Aneurysms

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Abstract: The fluid mechanics community has been interested for many years in hemodynamics. More recently, significant endeavours of the solid mechanics community have permitted to establish constitutive equations and to achieve stress analyses in arterial lesions (atheromatous plaque in coronary or carotid arteries, aneurysms of the aorta). The mechanical properties of blood vessels have often been characterized *ex vivo*, but medical imaging, including MRI, now allows non-intrusive identifications *in vivo*. The spatial heterogeneity of these mechanical properties, even at the macroscopic scale, remains poorly explored despite its undeniable interest in understanding the mechanisms of remodeling and degeneration of the tissue. We are interested in the problem of identifying the fields of mechanical properties of aneurysms of the aorta. Scientific barriers are related to the complex geometry, the nonlinear and anisotropic behavior of tissues, the multiaxial loading conditions, and to the measurement of a local response in these tissues. Our identification approaches, based on digital image correlation field measurements and inverse methods, have demonstrated the link between the heterogeneity of mechanical properties and the existence of localized failure modes. A micromechanical approach has also made it possible to develop a mechanobiological model to reproduce the behavior of the aorta in surgical situations and a simulation software is being developed for assistance to personalized surgery in the cardiovascular field.

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Stéphane Avril is a distinguished Full Professor at Institut Mines Telecom (IMT) affiliated at Mines Saint-Etienne and Université de Lyon in France. He runs a group of 20+ in soft tissue biomechanics, with a special focus on constitutive modeling and identification using imaging techniques. He is also director of the CIS Center for Biomedical and Healthcare Engineering (65+ people) and deputy director of SAINBIOSE (INSERM endorsed laboratory with 100+ researchers). Stéphane received his PhD in mechanical and civil engineering in 2002 at Mines Saint-Etienne (France). After positions at Arts et Métiers ParisTech (France) and Loughborough University (UK) where he developed the Virtual Fields Methods, Stéphane returned to his alma mater in 2008 and extended his broad experience of inverse problems to soft tissue biomechanics, especially regarding aortic aneurisms in close collaboration with vascular surgeons. Stéphane was a visiting Professor at the University of Michigan Ann Arbor (USA) in 2008 and has been a visiting professor at Yale University since 2014.

Stéphane has received several awards and distinctions including ICCB best communication award (2017), Editor's Choice Paper Finalist-ASME Journal of Biomechanical Engineering (2016), ESB best poster award (2015), BSSM 50th Anniversary Plenary Speaker (2014). He has led two national ANR grants in soft tissue biomechanics and supervised 25+ PhD students. In 2015, Stéphane was awarded an ERC (European Research Council) consolidator grant of 2m€ for the Biolochanics project on: localization in biomechanics and mechanobiology of aneurysms: towards personalized medicine.

Most of Stéphane's research is aimed at improving the treatment of cardiovascular diseases by assisting physicians and surgeons with biomechanical numerical simulations.
In 2017, Stéphane co-founded Predisurge, a spin-off company of IMT at Mines Saint-Etienne. PrediSurge offers innovative software solutions for patient-specific numerical simulation of surgical procedures. First applications in endovascular aneurysm repair (EVAR) enable the automatic design of fully-customized fenestrated stent-grafts. Preliminary evaluations reveal huge benefits for the 20000+ patients requiring fenestrated EVAR every year: faster procedures, increased precision, near-zero risk of complications. His vision for 2025 is that all EVAR procedures will have to be numerically simulated for ensuring the highest degree of safety.