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Title: An image-based computational framework for analyzing disease occurrence and treatment outcome in patients with peripheral arterial disease

Abstract:
Peripheral arterial disease (PAD) is generally attributed to the progressive vascular accumulation of lipoproteins that lead to the formation of atherosclerotic plaques in the lower extremities. The disease process is largely regulated by the local hemodynamics, and biophysical conditions. This emphasizes the importance of an accurate determination of the local flow field to potentially predict the occurrence of the disease and the outcome of any intervention. In this work, an isogeometric analysis framework is presented to investigate blood flow dynamics and vascular deposition of circulating nanoparticles (NPs) in the superficial femoral artery (SFA) of a PAD patient followed up over 24 months. The patient-specific geometry of the blood vessel and the hemodynamic conditions are derived from magnetic resonance imaging (MRI), performed at baseline and 24-months after stent-implantation. A dramatic improvement in blood flow dynamics is observed post-intervention resulting in a 500% increase in peak flow rate as a consequence of luminal enlargement. Furthermore, flow simulations reveal a 32% drop in mean oscillatory shear index (OSI), indicating reduced disturbed flow post-intervention. The same patient data are then used to predict in-silico the vascular deposition of systemically injected nanomedicines targeted to inflammatory cell adhesion molecules (CAMs) such as VCAM-1, that are known to overexpress at the diseased site. Results show that VCAM-1 directed NPs preferentially accumulate near the stenosis in the baseline configuration. Such selective deposition of NPs could be effectively used for the non-invasive detection and treatment of plaques forming in the SFA. The proposed MRI-based computational protocol can therefore be utilized to retrospectively analyze data from clinical trials to explore possible correlations between hemodynamics and disease progression in PAD patients, and to provide predictive insight into disease management.