

Towards patient-specific modelling of Atherosclerotic Arterial Sections

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ABSTRACT

Atherosclerotic plaques (within the coronaries) could produce stenosis and blood flux to decrease in the vessel, thrombosis, or rupture. Typically a patient presents either stable or unstable (low or high risk of rupture) plaque. A fast diagnosis identifying to which of these two groups the patient belongs to is crucial for its treatment and disposition [1]. A combination of biomechanical and image-based markers may help to improve the differentiation of these two groups of patients [2, 3]. In this regard, a methodology to determine these biomechanical markers to be seamlessly incorporated into the clinical pipeline is of great use and facilitates the translation of this technology to the clinic.

To deal with patient-specific data-driven models, we aim for flexibility, supporting all cases on the same mesh using an unfitted approach. Thus, we propose an unfitted immersed boundary-based methodology in addition to a more physical elastic-bed boundary condition to analyze coronary artery sections undergoing uniform pressure in a quasi-static regime. The framework assumes a linear elastic behavior for the coronary artery components. The elastic bed represents the materials (assumed to have linear properties and characterized by α , the elastic bed coefficient) surrounding the artery. This modeling approach guarantees the uniqueness of the solution while obtaining more physical displacements and stresses when compared with a classical Dirichlet boundary condition.

With a modified version of hierarchical level sets [4], we define an IB approach extending our model. The level sets provide an implicit description (material and geometry) of a particular section over a fixed background mesh, namely the voxelized medical image. Then, we can perform simulations for different patient-specific geometries from initial segmented medical images, avoiding individual meshing and preprocessing steps. Segmented images provide the boundaries of the distinct components as level sets, and the IB approach simulates stresses on a voxelized background, with the possibility of refinement to increase accuracy.

In addition, having a unique computational domain lays the foundation for Proper Orthogonal Decomposition (or other methods of complexity reduction) that can be useful for improving simulation speed and plaque classification (low versus high risk) to support the decision-making process in hospitals.

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