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A Reduced Order Model For Efficient Physiological Flow Analysis In Aneurysms by Proper Orthogonal Decomposition

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Abstract

Simulating physiological flows using computational fluid dynamics (CFD) remains to be computationally expensive and difficult for clinical usage because of the physiological flow and geometrical complexity involved in patient specific situations. We use the reduced order modeling (ROM) of such systems with high nonlinearity and geometrical non-uniformity to replace the full, nonlinear model with a low-degrees of freedom ROM model. We construct ROM models by the proper orthogonal decomposition (POD) method to estimate the flow-induced wall shear stress (WSS) and pressure loading of a simplified abdominal aortic aneurysm and a bifurcation cerebral aneurysm. This method allows us to investigate a wide range of different physiological flow parameters without conducting the computationally expensive CFD simulations repetitively, which is promising for clinical usage.

We obtain a set of snapshots from a set of flow simulations with multiple variable parameters, called the training set. The training set should be simulated in a parameter space that contains all the physiological parameters of interest. We show that both the velocity and pressure distributions are well reconstructed when compared with the exact values with a small number of modes. A mesh-less shell model is used to estimate the aneurysm sidewall's in-plane stresses. Sidewalls with non-uniform thickness are considered to study the influence of local weakness on the aneurysm's risk of failure. We found that the sensitivity of the material's strength to the local weakness depends on the aneurysms sidewall's Gaussian curvatures, the curvature to thickness ratio and the distribution of the flow loading. It is therefore critical to describe the distribution of curvature and thickness accurately when estimating the in-plane stress of aneurysms.

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