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LAGRANGIAN ANALYSIS OF REST AND EXERCISE HEMODYNAMICS IN PATIENT-SPECIFIC ABDOMINAL AORTIC ANEURYSM MODELS

***Shawn C. Shadden[1], Andrea S. Les[2] and Charles A. Taylor[3]**

[1] Bioengineering
Stanford University
318 Campus Dr.
Stanford, CA 94305-5431
sshadden@gmail.com
http://stanford.edu/~shadden/

[2] Bioengineering
Stanford University
318 Campus Dr.
Stanford, CA 94305-5431
asles@stanford.edu

[3] Bioengineering
Stanford University
318 Campus Dr.
Stanford, CA 94305-5431
taylorca@stanford.edu
http://taylorlab.stanford.edu

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ABSTRACT

Purpose: The development and growth of abdominal aortic aneurysms (AAAs) is due to a highly dynamic interation between blood flow mechanics, vessel wall mechanics, and biochemical cellular interactions. Our goal is to apply computational methods to analyze blood flow kinematics in patient-specific AAA models to characterize how blood is transported in realistic aneurysm geometries. Since recirculation and stagnation are thought to play an important role in inflammation and thrombus formation we focus on quatifying these conditions. In addition, we study whether simulated exercise produces benificial AAA hemodynamics in comparison to resting conditions.

Methods: Three-dimensional magnetic resonance angiography data was used to construct patient-specific geometric models [1]. Blood flow was simulated on a highly-resolved, unstructured computational mesh by solving the Navier-Stokes equations using a stabilized finite element method [2,3]. A Newtonian fluid and rigid walls were assumed. Inlet boundary conditions were prescribed from *in vivo* flow rate data and the coupled multidomain method [4] was used to prescribe lumped-parameter outlet boundary conditions to match measured pressure pulse and flow distributions. This data was used to compute several Lagrangian descriptors, including particle residence time, finite-time Lyapunov exponent fields and Lagrangian Coherent Structures (LCS) [5].

Results: Flow through the aneurysms was highly complex. Although fully-developed turbulence never occurred, transient turbulent conditions were observed during both rest and exercise in all models. Computations of LCS reveal the template for complex mixing in the AAAs. These LCS provide distinct separatrices, which partition flow that is quickly flushed from the aneurysm and flow that recirculates or remains stagnant. In most cases, simulated exercise greatly reduced the locations of flow stagnation in the aneurysm when compared to resting conditions, see Fig. 1.

Discussion: Previous studies of AAA hemodynamics have used idealized models, or when patient-specific models are used, the computations are often under-resolved. Furthermore, only Eulerian criterion are typically considered in evaluating the hemodynamics. We demonstrate that flow though realistic AAAs is highly complex and significantly different than idealized AAA flow. Lagrangian analysis, such as considered here, is essential to understanding the hemodynamics due to the unsteadiness

of the flow. The methods presented enable a much clearer understanding of how transport occurs in realistic AAA geometries than previous analyses.

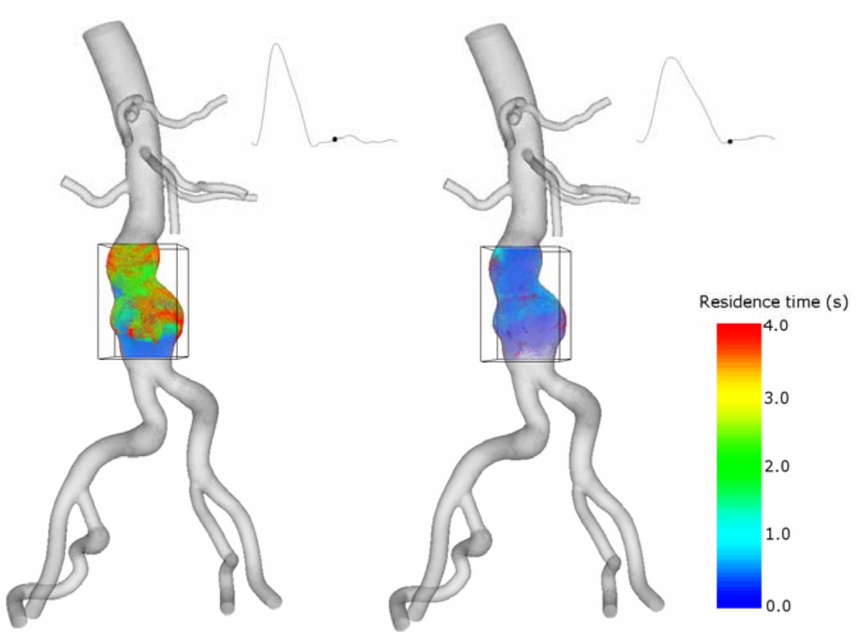

Figure 1 Residence time distribution inside a patient-specific AAA model in diastole for rest (left) and exercise (right). Regions of stagnant, recirculating flow are greatly reduced during exercise.

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