CARNEGIE MELLON UNIVERSITY
BME 2025 SPRING SEMINAR SERIES

BIOMEDICAL ENGINEERING
Carnegie Mellon University

Fluid Mechanics of Intracranial Aneurysms: Fundamental aspects and application to clinical decision-making

PRESENTED BY

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SCHEDULE

Doherty Hall (DH) 2315

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The fluid mechanics inside intracranial aneurysms dominate the efficacy of endovascular treatment methods, modulating the mechanical stresses and residence times inside the sac and at the aneurysmal neck. Embolic coils and flow-diverting stents, the two dominant types of endovascular devices for treatment, are designed to slow down flow inside the aneurysmal volume and reduce stresses on the aneurysmal sac, creating an environment that enables successful thrombosis in the aneurysm, which eliminates the risk of rupture.

In-vitro experiments characterize the hemodynamics inside intracranial aneurysms, prior to treatment and post-treatment with flow-diverting stents. We use stereo (2D-3C) and 3D (3D-3C) particle image velocimetry (PIV) to explore the parameter space of aneurysms in a large cohort of patients followed along several years. The flow measurements are interpreted as a combination of two canonical flows: flow in a curved pipe and cavity flow. As such, the parent-vessel Reynolds and Dean numbers are the relevant non-dimensional parameters. Unsteadiness in the cardiac cycle introduces the Womersley number as a third component of flow inertia. Despite inertia dominating the parent-vessel flow, flow-diverting stents significantly reduce the velocity inside the aneurysmal sac, leading to viscous-dominated flow. A critical Dean number is identified that separates two opposite flow behaviors that could help predict treatment success.

I will also discuss a computational investigation of a large population of patients whose aneurysm treatments are followed over time, to determine the mechanism by which endovascular treatment fails to prevent aneurysmal growth. A novel modeling technique that uses high-resolution, synchrotron micro-CT scans to understand the flow inside coiled aneurysm enables homogenization methods for improved porous medium representation of deployed coils or stents, improving the clinical utility of the simulation results.