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IMPACT OF FLOW RATE ON WALL VIBRATION IN INTRACRANIAL ANEURYSMS

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Recent computational fluid dynamics (CFD) studies have suggested that high-frequency, harmonic flow phenomena may be associated with the rupture of intracranial aneurysms (IAs) [1]. These high frequency flow phenomena have been observed in vivo and are known to produce sound at frequencies between 150-800 Hz [2], [3]. The aim of this study was to begin to understand the relationship between these flow phenomena and wall vibration/degradation, using a new monolithic solver capable of efficiently resolving high-frequency fluid-structure interactions, turtleFSI [4],[5].

Specifically, the current study aimed to subject a single IA geometry to varying levels of flow instability within physiologically plausible levels by applying a gradually increasing (ramped) flow rate for a total simulation time of 5.5s. This specific geometry was previously shown to exhibit both mildly unstable flow and highly unstable flow under different physiological flow rates from previous CFD.

The aneurysm exhibited flow with spectral banding immediately after the onset of flow instability, with the flow later transitioning to a less banded, highly unstable flow. Wall vibrations on the order of 1 micron were detected after the onset of flow instability, while there was no vibration prior to the onset of flow instability. The vibrations were found to consist of two types: (1) chaotic vibration that mirrored the frequncy content of the fluid flow, and (2) “rocking” modes of the entire aneurysm sac at distinct frequencies that did not present as frequency bands in the fluid flow. The most prominent modes occurred between 50 and 400 Hz. Overall vibration amplitude generally increased as flow rate and flow instability increased, however, the two most prominent “rocking” modes at 310 and 390 Hz were reduced in amplitude when the flow was most unstable. These results are the first to (1) describe in detail the flow phenomena that cause wall vibration in IAs, and (2) to break IA wall vibrations into distinct mode shapes.

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