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Carotid Artery Digital Twin Based On Reduced-Order Model

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Extended Abstract

In the current global health context, stroke has emerged as the third most prominent cause of mortality, following cardiovascular disease and neoplasms, substantially impacting human health. A primary etiological factor of stroke is carotid artery stenosis, which is predominantly caused by the build-up of atherosclerotic plaque [1]. Furthermore, the formation and development of atherosclerotic plaques are highly influenced by the hemodynamic environment in the carotid artery [2]. However, the impact of an elevated heart rate on the hemodynamic milieu in carotid arteries of differing stenosis degrees, utilizing healthy carotid arteries as reference controls, has been seldom reported in the open literature.

To address the research gap, digital twins of both healthy carotid arteries and those with varying degrees of stenosis were constructed in this work. Specifically, computational fluid dynamics (CFD) simulations on carotid arteries exhibiting varying degrees of stenosis were conducted to procure hemodynamic results under various heart rates [3]. The reduced order model (ROM) Builder Pre module was employed to export the simulation results as training files, encompassing solely grid node coordinates and individual hemodynamic parameters (e.g., velocity, pressure, and wall shear stress) [4, 5]. Subsequently, the Ansys Twin Builder module's reduced-order model derived a correlation between each grid node's hemodynamic parameters and the inlet boundary, thereby constructing a digital twin of the carotid artery. By modulating the inlet velocity of this digital twin, we obtained the distribution of hemodynamic parameters in the carotid artery in real-time response, thus enabling real-time visualization of flow field distribution under various heart rates. Contrasting with high-order models that employ Navier-Stokes equations to solve for carotid artery hemodynamic parameters in each scenario, the ROM necessitates only the training of hemodynamic results from typical previous scenarios.

The present work is expected to shed light on the deleterious implications of an augmented heart rate during physical exercise in individuals afflicted with carotid artery stenosis. The advent of a digital twin is poised to significantly broaden the spectrum of heart rates encompassed in this research.

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