ABSTRACT FACE PAGE

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11. **Is this the research presented in this abstract supported by IMAG MSM-related U01 funding?** Yes, MSM-U01HL116323.
12. **If the Presenting Author is a trainee, who is the trainee's primary research advisor?** N/A

TRANSFER LEARNING ON PHYSICS-INFORMED NEURAL NETWORKS FOR TRACKING HEMODYNAMICS IN EVOLVING FALSE LUMEN OF DISSECTED AORTAS

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BACKGROUND: Thoracic aortic dissection (AD) is a cardiovascular pathology caused by a tear or rupture in the intimal layer of the aortic wall, allowing blood to flow in and dissect the intimal and medial layer of the arterial wall [1]. These dissections often propagate within the media and connect with the original aortic lumen (true lumen) to form a so-called "false lumen" within the aortic wall. The dissected aortas are susceptible to rupture due to the weakened vessel wall, potentially leading to a life-threatening crisis. In the last two decades, computational fluid dynamics (CFD), which simulate the blood flow based on Navier-Stokes equations, has been broadly employed to illustrate the complex blood flow patterns in blood vessels with pathological alterations to assist the disease prognosis of various cardiovascular diseases. However, CFD simulations entail large memory resources, time-consuming computation and cumbersome preprocessing, such as mesh generation for geometries and boundary condition setup, which prevent their deployment to clinic settings.

METHODS: We propose to utilize transfer learning on physics-informed neural networks (PINNs), which can integrate Navier-Stokes equations and data measurements (e.g., MRI, Ultrasound) into the loss function of NNs, to resolve flow field in the simulation domain without mesh generation or knowledge of flow boundary conditions [2]. We examine the performance of PINNs by predicting the hemodynamics in realistic 3D dissected aortas reconstructed from the apolipoprotein null mice infused with AngII [3]. Our results show that PINNs can assess hemodynamics in the false lumen without modeling the true lumen and various branched vessels, thereby reducing the amount of required measurement data and dependency on boundary conditions. Moreover, we will demonstrate that by employing transfer learning, the trained PINNs model can predict the hemodynamics in the evolving false lumen with minimal retraining, thereby reducing the time and financial cost of follow-up examinations of AD patients.

RESULTS: As illustrated in Fig.1, we find a good agreement between the predictions of PINNs and the CFD simulations. We also investigate the impact of temporal and spatial resolution of measurement data on the accuracy of PINNs predictions. Our results show that dissecting aneurysms with large tear require higher temporal resolution whereas the smaller tear had about equal dependence on both temporal and spatial resolutions. This finding suggests that the size of the tear can be used as a metric to determine the optimal resolution required for data measurements. Additionally, our results show that implementation of transfer learning to the PINNs model can increase the efficiency of the model performance on making prediction in the progressed dissecting aneurysms.

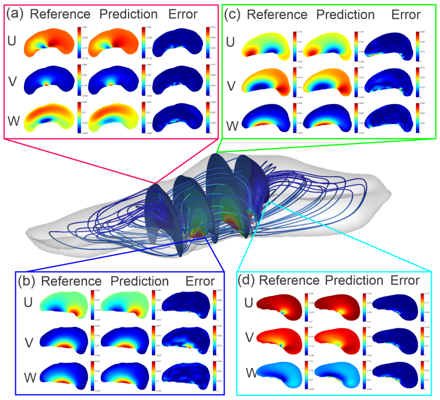

Figure 1: Realistic geometries of dissecting aortic aneurysms reconstructed from mice are employed to examine the accuracy and efficiency of the proposed PINNs model.

CONCLUSIONS: We demonstrate that by employing transfer learning on PINNs, we can track the hemodynamics in the evolving false lumen of dissected aorta with reduced data acquisition and computational cost, thereby facilitating its applications in clinical practice. This new computational framework has a broader impact as it can be applied to study diverse aneurysms, such as cerebral aneurysms and abdominal aortic aneurysms.

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