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Personalized Stroke Risk Assessment in Atrial Fibrillation Using Fluid-Structure Interaction and Deep Learning

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Extended Abstract

Atrial fibrillation (AF) is a heart rhythm disorder, representing a major risk factor for ischemic stroke. In patients with AF, the left atrial appendage (LAA) is the predominant site of thrombus formation, primarily due to blood stasis and disrupted haemodynamics [1,2]. Despite a number of computational studies of the LAA hemodynamics have been based on rigid wall computational fluid dynamics (CFD) analyses [3], it has been shown that integrating the effect of the LAA walls through fluid-structure interaction (FSI) simulations is necessary to achieve a more faithful representation of physiological conditions [4,5]. Nevertheless, FSI simulations require more specialised expertise and considerably longer computational costs, making them less attractive for routine clinical use.

In order to overcome this limitation, this study presents a deep-learning framework trained on FSI simulations performed on a synthetically generated dataset of LAA geometries derived from a statistical shape modelling pipeline [6]. Unlike traditional CFD approaches, which are also employed as input data in deep learning research [7], the use of FSI analysis is expected to enhance the fidelity of training data to replicate physiological conditions and extract relevant haemodynamic descriptors such as the shear strain rate (SSR).

Simulation results are used to compute the blood stasis factor (BSF), a biomarker that identifies regions exposed to prolonged stagnation and represents an indicator of the thrombogenic risk [4].

To enable rapid and scalable inference, a dynamic graph convolutional neural network (DGCNN) was trained [7]. The network model receives as input the point cloud representations of a generic LAA anatomy and gives as output the SRR predicted for each point, allowing the estimation of the thrombotic risk associated to the specific LAA.

This work introduces a new computational paradigm for stroke risk evaluation in AF patients, linking physics-based simulations and real-time predictive modelling. By coupling FSI simulations with deep learning, the proposed approach provides a physiologically grounded, clinically scalable tool for thrombosis risk assessment. This deep learning-based approach may offer a faster and more accessible tool, supporting clinicians in the efficient assessment of thrombotic risk.

Future developments will focus on the use of patient-specific imaging data and the integration into decision-support systems for personalised stroke prevention.

Keywords

Atrial Fibrillation (AF); Left Atrial Appendage (LAA); Fluid-Structure Interaction (FSI); Deep Learning; Thrombotic Risk Stratification;

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