Left Atrial Appendage Flow Stagnation in Atrial Fibrillation Patients Assessed with Computational Fluid Dynamics

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Summary

We apply a dynamic computational fluid dynamics (CFD) model of the left atrium (LA) to 26 patients with atrial fibrillation (AF). The results underline the haemodynamic differences between the LA and left atrial appendage (LAA), the latter having a high level of stasis. LAA flow stagnation is further correlated with indexed LA volume (p=0.003), suggesting potential predictive value for thrombi.

Introduction

AF is characterized by a rapid and irregular heart rhythm, leading to disturbed haemodynamics within the LA. Such conditions and their tendency to promote thrombosis are thought to be the cause of a five-fold increased risk of stroke in AF patients [1]. Whilst 4D flow MRI enables the assessment of large-scale fluid structures, the relatively low resolution presents a challenge for the analysis of shear conditions, particularly in the LAA. CFD offers an opportunity to observe haemodynamics in very high spatial and temporal resolutions.

Methods

We applied a previously developed and validated CFD model of the LA to 26 AF patients, all in sinus rhythm during imaging. Briefly, our simulations were based on high resolution 3D reconstructions from CT as well as inlet flows and LA wall motion from 4D flow MRI [2]. This model assumes a laminar flow regime and non-Newtonian Carreau-Yasuda blood viscosity. Simulations were run for 5 cardiac cycles with a constant time step of 0.001s on 224 cores of the McMeSU supercomputer. Haemodynamic metrics such as time-averaged wall shear stress (TAWSS), oscillatory shear index (OSI) and relative residence time (RRT) were averaged over the final cycle. To assess hemodynamic differences between the LA and LAA, a two-tailed Student's t-test was applied after checking normality using a Shapiro-Wilk test. Linear regression was used to assess the relationship between indexed (by body surface area) LA volume and LA/LAA RRT.

Results and Discussion

As observed in previous studies [3], the LAA is susceptible t o highly stagnant conditions with much lower TAWSS ($p<0.0001$) along with higher OSI ($p<0.0001$) and RRT ($p<0.0001$), compared to the rest of the LA. Increased indexed LA volume, which is associated with progressive degradation of atrial wall muscle, was significantly correlated with increased RRT in both the LA ($p=0.016$) and LAA ($p=0.003$) (Fig. 1).

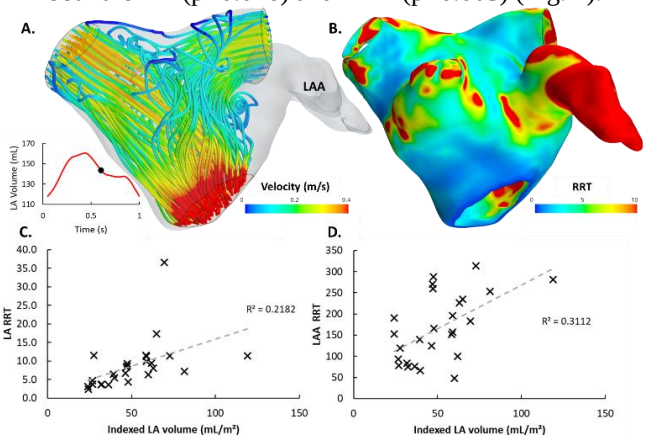

Figure 1: A. Velocity streamlines in one case (timepoint indicated on LA volume curve). B. RRT for the same case. C. The relationship between indexed LA volume and LA (C.) and LAA RRT (D.).

Conclusions

We have simulated the complex LA dynamics of a group of AF patients while combining CFD with supercomputing resources. The results suggest that the haemodynamic conditions underlying thrombus development in the LAA, which precede embolic stroke, are correlated with the highly accessible global measure of indexed LA volume. This may be of clinical use in predicting thrombotic events.

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