IMPACT OF VESSEL MORPHOLOGY ON HEMODYNAMICS OF LENTICULOSTRIATE ARTERIES DURING ATRIAL FIBRILLATION

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Introduction

Lenticulostriate arteries (LSAs) are small perforating arteries mainly departing from the middle cerebral artery (MCA) and, less frequently, from the anterior cerebral artery (ACA). These arteries are responsible for supplying blood to important deep brain structures such as the basal ganglia. LSAs are susceptible to small vessel disease, which is one of the main mechanisms of subcortical vascular dementia development [1]. In addition, there is growing evidence that an alteration of deep cerebral hemodynamics due to atrial fibrillation (AF) increases the risk of vascular dementia and cognitive impairment [2]. In this complex context, an important role could be played by the almost orthogonal branching of these vessels. The purpose of this study, which combines CFD analysis of LSAs with 7T high-resolution magnetic resonance imaging (MRI), is to investigate the impact of different LSAs morphologies on cerebral hemodynamics during AF events.

Methods

High-resolution 7T cerebral MRI data of 10 subjects were used for the reconstruction of the vasculature geometry leading to a total of 17 segmented LSAs. To perform 3D CFD simulations, a validated 0D cardiovascular-cerebral model [3], which simulates the cerebral hemodynamics in AF and sinus rhythm (SR), was used to obtain inlet and outlet conditions. By the Vascular Modeling Toolkit (VMTK) a number of subject-specific geometric characteristics (tortuosity, radius, bifurcation angles) were extracted. Relationships between wall shear stress (WSS) pattern in LSAs inlets and morphological features were assessed by multiple regressions. In particular, the hemodynamic variable investigated was the ΔWSS, which was defined as the difference between the WSS magnitude obtained in correspondence of the 95th percentile of $p(Q_{max})$ and the one obtained at the 5th percentile of $p(Q_{min})$, where $p(Q_{max})$ and $p(Q_{min})$ are respectively the probability density functions of the maximum and minimum values *per* beat of the MCA flow rate time series, which was 5000 beats long.

Results

During AF the LSAs proximal regions were exposed to an increased range of WSS compared to SR (see Fig. 1). Moreover, regressions revealed a statistically significant correlation between some of the geometric characteristics and the 90th percentile values of the WSS range (ΔWSS).

Discussion

The present study shows how the local hemodynamics of lenticulostriate arteries may be affected by their morphologies, such as different MCA or ACA radii in the bifurcation proximity or different in-plane bifurcation angles. This suggests that LSAs with particular morphologies may be more prone to vascular disease.

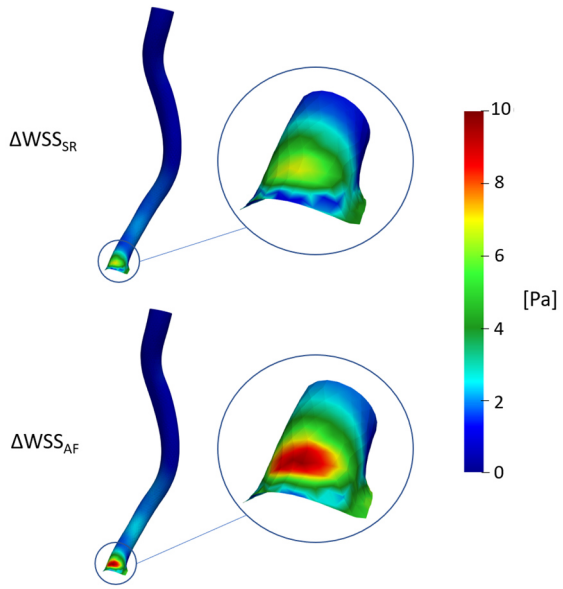

Figure 1: CFD model of a representative LSA displaying local ΔWSS: SR (top) and AF (bottom).

References

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