Left Atrium Hemodynamic in Atrial Fibrillation and Normal Subjects

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Background

A computational fluid-dynamics (CFD) model previously developed with the aim of evaluating cardioembolic risk in patient affected by atrial fibrillation (AF) was used for the characterization of the left atrium (LA) hemodynamic in normal subjects (NL), patients affected by paroxysmal atrial fibrillation (PAR-AF) and patients affected by persistent atrial fibrillation (PER-AF).

Objective

Based on the fluid-dynamics simulations results, we aimed at enhancing differences in blood flow in AF patients and NL and at better understanding the relationship between AF progression and stroke risk on a patient-specific basis.

Methods

3D patient-specific anatomical and motion models were derived from ECG-gated coronary artery CTs acquired with retrospective protocol. These models represented the computational domain for CFD simulations in which inflow initial conditions were derived from PW Doppler at the mitral valve and at the pulmonary veins. Velocity field and vortex structures both within the LA and left atrial appendage (LAA) were assessed in 10 NL, 5 PAR-AF and 4 PER-AF. Blood stasis was evaluated by populating the LAA with 500 particles and counting the number of particles still present after five cardiac cycles.

Results

Velocities inside the LA and in the LAA presented different amplitude and distribution in the 3 groups (peak velocity – NL: 50÷60 cm/s, PAR-AF: 40÷50 cm/s, PER-AF: 15÷25 cm/s). The mean velocity resulted lower in the PAR-AF compared with PERS-AF (mean velocity – PAR-AF: 25÷35 cm/s, PER-AF: 8÷20 cm/s) at the LAA ostium and inside the LAA, in which the wash-out effect was strongly reduced (Figure 1). On the other hand, the mean velocity in the NL was higher with respect of AF patients (mean velocity – NL: 40÷45 cm/s). A higher number of vortex structures was observed in NL compared with AF patients, thus favoring the hypothesis of a more efficient wash-out of the LA and of the LAA. The fluid particle analysis in the LAA confirmed these results (NL: 5±2, PAR-AF: 18±3, PER-AF: 41±10).

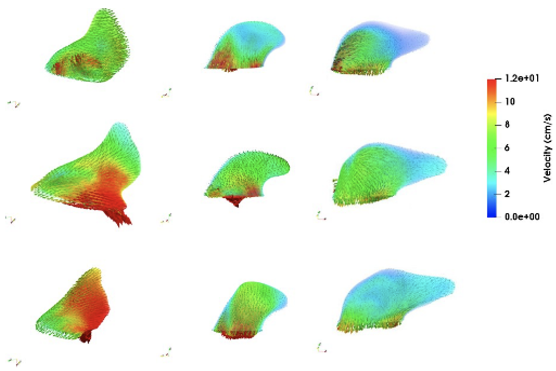

Figure 1: LAA velocity fields in 3 representative subjects (NL, PAR-AF and PER-AF in the 1st, 2nd and 3rd column respectively), in three phases of the cardiac cycle (1st row: ventricular systole, 2nd row: ventricular diastole, 3rd row: atrial systole).

Discussion

Velocities within the LA and LAA showed higher values in the NL subjects with respect to PAR-AF and PER-AF patients. The lowest values within the LA and LAA were observed in the PER-AF group that could imply a higher probability of blood stasis and consequently an increase of stroke risk. In PAR-AF patients the contractility was not strongly reduced as for the PER-AF patients thus leading to higher values of the velocities and a stronger LA contraction/expansion with respect to the PER-AF. This may reduce the probability of clot formation. In addition, vortex structures, LAA ostium velocity, and the LAA residence time analysis confirmed what we qualitatively expected about the differences of the three groups. The developed approach quantifies differences in LA hemodynamic between AF and NL patients, also allowing a stratification of the disease progression in terms of variations in the blood velocity, organization of blood flow and quantification of blood stasis.