Influence Of Ventricular Torsion On Left Ventricular Hemodynamics: A Patient-Specific Model Using The Chimera Technique

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Abstract: Image-based patient specific cardiovascular Computational Fluid Dynamics (CFD) models of the left ventricle (LV) can provide hemodynamics-based biomarkers beyond the capabilities of current imaging modalities, quantifying intraventricular flow and providing clinicians with additional data for early diagnosis, follow-up and treatment planning of patients. A CFD modelling pipeline [1], based on 3D ultrasound and on an Arbitrary Lagrangian Eulerian approach, struggled with numerical convergence issues mainly due to the complex kinematics of both LV endocardium and Mitral Valve (MV) leaflets, leading to mesh-related problems. In this context, we developed a more robust workflow to build patient-specific CFD models of the LV based on the Chimera technique, which is still relatively unemployed within the biofluids community. As an application, we investigated whether torsional motion has an impact on the LV fluid dynamics. We developed a subject-specific LV model from 3D MRI scans and compared three CFD cases where we imposed LV motion (i) without any torsion (no Torsion), (ii) with physiological torsional motion (Torsion X1) and (iii) with torsion multiplied by a factor 2 (Torsion X2). Six cardiac cycles were simulated. Firstly, we observed an important cycle-to-cycle variation in every simulated case (with results shown for the Torsion X1 in Figure 1). Secondly, torsion leads to only minor differences in the spatial distribution and maximum values of velocity and vorticity (Figure 2A, 2B), with the main differences located in the medial plane (SA2). Third, the percentage of the particles staying more than 2 cardiac cycles is 11.4%,17.9%,15.6% in the no Torsion, Torsion X1, Torsion X2 cases, respectively. We conclude that the chimera technique proved robust in setting up a subject-specific CFD model of the LV. Torsion does not seem to have a major impact on wall shear stress or on vorticity. The impact of torsion on RT is somewhat larger and unexpected, but caution is warranted given the physical absence of the mitral valve (MV), the papillary muscles and the trabeculae. The effects of the MV will be evaluated within a FSI simulation framework as further development of the current model.

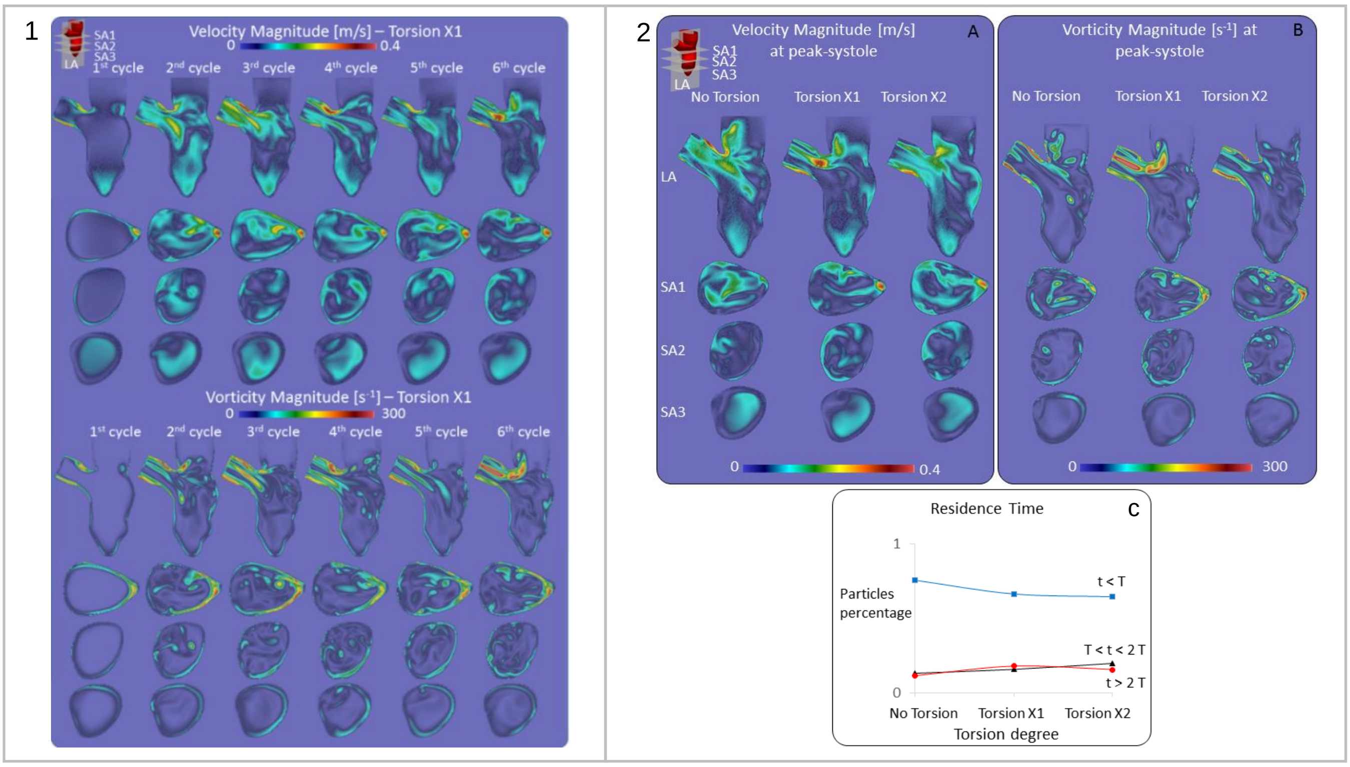

Figure Caption: (1) Cycle-to-cycle variation of velocity and vorticity magnitude during end systole in the Torsion X1 case; (2) Investigated variables to evaluate the impact of torsion in the 3 simulated cases.SA: short axis; LA: long axis.

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References: [1] Bavo, A et al., J Biomech, 50:144-150, 2017.