An investigation of atrial inflow conditions and their effect on the ventricular flow pattern during ventricular assist device support

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Introduction: Usually simulation of the ventricular flow patterns is based on straight inflow conditions from the atrium without considering asymmetries arising from the contribution of pulmonary veins. In this study, the influences of the atrial flow conditions including rotation and asymmetric flow profiles on the intraventricular flow patterns were investigated via Computational Fluid Dynamics (CFD) simulations.

Methods: A left ventricular model with a mechanical support device was used for three different simulations with laminar methods. At first was performed with normal velocity at the inflow as a validation study against PIV (pump speed: 2800 rpm, flow rate: 3.5 lit/min), secondly added a rotational component to the velocity field at the inflow (30 rpm) and third with an asymmetric inflow combining (60%/40% left/right flow ratio to replicate physiologic uneven flow distribution of the pulmonary veins). Deviation of the velocity angle with respect to normal velocity at the inflow, as well as stagnation areas (velocity¡0.01m/s) and instability of the vortical structures from the standard deviation (STD) of Q-value were calculated.

Results: The measured and calculated velocity angles at the ventricular inflow in the symmetric condition were comparable (PIV: 0.6°, CFD: 1.2°). By adding rotation or radial asymmetry these angles changed (CFDrot: 3.8°, CFDasym: -4.2°). With the rotational velocity at the inflow, less stagnation areas were detected (CFDrot: 3.4 cm^2, CFD: 4.9 cm^2, CFDasym: 4.6 cm^2). Unstable vortex structures occurred when comparing inflow rotation and asymmetry with straight profile (STD of Q-value, CFD: 0.07 vs. CFDrot: 0.1, CFDasym: 0.09).

Conclusions: Neglecting the atrial flow conditions could lead to inaccurate simulation of the ventricular flow pattern. Hence, reliable prediction of ventricular stagnation areas and recirculation zones requires also the consideration of the atrial inflow conditions.