HEMODYNAMIC COMPARISON OF BIOPROSTHETIC VALVES BASED ON IN VITRO 4D FLOW MRI

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Introduction

Bioprosthetic valves (BPVs) are largely employed for surgical aortic valve replacement [1]. In patients with small roots proper BPV selection is crucial to avoid risk of residual transvalvular gradients. To promote both comprehensive and consistent comparison among different BPVs, we herein combined 4D flow magnetic resonance imaging (MRI) with a standardized in vitro setting to map hemodynamic performances of BPVs.

Methods

4D Flow was acquired on a Magnetom Aera 1.5T (Siemens Healthcare, Erlangen, Germany) for the TrifectaTM, the Carpentier-Edwards PERIMOUNT Magna and the Crown PRT® pericardial BPVs [2], selecting the two smallest sizes. Each BPV was tested under steady flow conditions on an *in vitro* MRI-compatible system equipped with pressure transducers and including an aortic root phantom (*Figure 1*).

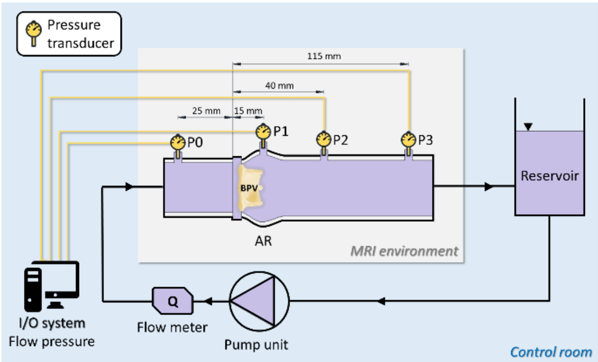

Figure 1: In vitro 4D Flow-based set-up.

Hemodynamics was compared among BPVs in terms of 3D velocity field, peak of velocity (V_{MAX}), effective orifice area (EOA), transvalvular pressure drop (TPG), kinetic energy (KE) and viscous energy dissipation ($\dot{E}_L$). 4D Flow-based pressures were compared with ground-truth data from transducers.

Results

4D Flow effectively captured the 3D flow pattern of each BPV, its core jet isosurface and the actual EOA shape (*Figure 2.A*). Trifecta reported the lowest V_{MAX} for both the tested sizes ($p < 0.001$), maximized EOA ($p \leq 0.0002$) and minimized TPGs ($p \leq 0.015$) if compared with Magna and Crown, these reporting minor EOA differences and comparable TPGs ($p \geq 0.25$). Also, EOA shape was trilobal for Magna, triangular for Crown and circular for Trifecta, this also reporting the most proximal position for *vena contracta* (*Figure 2.B*). 4D Flow-derived TPGs strongly correlated ($r^2 \geq 0.89$) against ground-truth data from the pressure transducers; $\dot{E}_L$ proved to be inversely proportional to the fluid jet penetration.

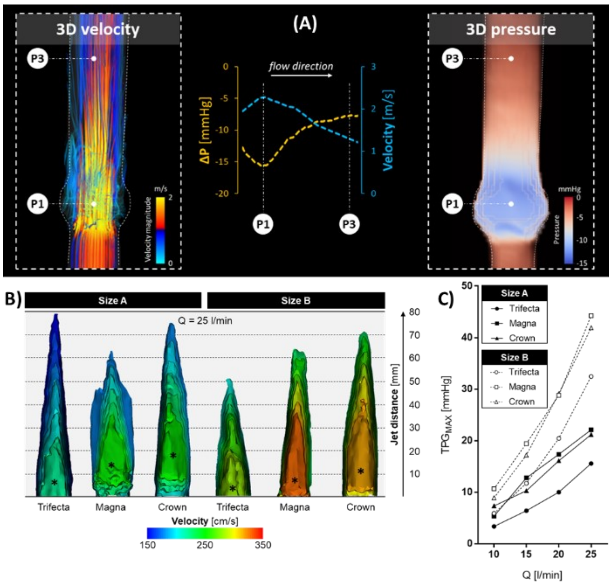

Figure 2: 4D Flow post-processing (A), BPV-specific 3D velocity flow pattern (B) and TPG comparison.

Discussion

The proposed 4D Flow analysis pinpointed consistent hemodynamic differences among BPVs, highlighting that both design and size of pericardial BPVs directly impact on the downstream flow field pattern. To enable pulsatile flow conditions, inclusion of a pulsatile MR-compatible pump unit in the vitro system is on-going.
The efficacy of non-invasive 4D Flow MRI could shed light on how standardize the comparison among BPVs in relation to their actual hemodynamic performances. If further extended, the protocol could also support pre-clinical assessment of prototypal cardiac valves and potentially reduce the need for animal testing.

References

1. Holmes *et al*, Circulation 135(18): 1749-1756, 2017
2. Sturla *et al*, Magn Reson Imaging 61: 18-29,2020

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