4D Flow analysis of intracavitary blood flow dynamics and energetics in the systemic right ventricle

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Background: The systemic position of a morphologically right ventricle (SRV) makes it vulnerable to fail, leading to high incidence of heart failure and cardiac death [1]. Understanding SRV intracavitary blood flow dynamics and energetics could improve patient risk stratification.

Purpose: Testing the potential of three-dimensional time-resolved phase contrast cardiac magnetic resonance (4D Flow) in quantifying SRV blood flow dynamics and energetics.

Methods: 4D Flow prototype sequences were acquired on 3 patients (1 male, 2 females) with SRV in D-loop transposition of great arteries after atrial switch operation (D-TGA/ASO), 3 male patients with SRV in L-loop TGA (L-TGA) and healthy controls (2 males, 1 female).

Kinetic energy (KE), viscous energy loss (EL), dissipation index (DI) calculated as EL to KE ratio, and hemodynamics forces (HFs) resulting from pressure gradients, were computed for the D-TGA/ASO and L-TGA SRVs, and for the control left ventricles (LVs) and right ventricles (RVs). HFs were decomposed in inferior-anterior, septal-lateral and basal-apical components (HFIA, HFSL, HFBA, respectively)

Results: Figure 1 reports the time-course of HF components and the general features of the enrolled subjects.

In systole, all SRVs (Figure 1a-1b) presented a dominant HFIA and a minor HFSL, similarly to RVs (Figure 1c); however, HFSL had a positive peak, indicating septal contraction towards the SRV cavity, opposite to its normal motion. HFBA magnitude was similar to LVs (Figure 1d), suggesting that the shortening of the tricuspid anulus towards the apex is more pronounced than in RVs (Figure 1c).

Over the whole cardiac cycle, DI values were highest in D-TGA/ASO SVRs (0.40-0.55); in L-TGA SRVs, DI values (0.24-0.45) were comparable to healthy LVs (0.22-0.37) and RVs (0.23-0.36). This difference may be related to the fact that in DTGA/ASO the left atrium is functionally replaced by a pulmonary venous baffle, which lacks efficient contraction, as highlighted by the absence of a distinctive A-wave in the KE time-course (Figure 2a).

Due to the adaptation to systemic afterload, SRVs were hypertrophic (Figure 1a-1b), with indexed mass higher than normal RVs (Figure 1c), and presented reduced compliance to the diastolic filling, as suggested by increased KE E-wave slope in L-TGA (Figure 2b) compared to controls (Figure 2c-2d).

Conclusions: Intracavitary HFs in SRVs reveal a partial shift from a RV towards LV pattern. This occurs at the expenses of a higher energetic consumption in D-TGA/ASO than L-TGA, enlightening the crucial role of atrial contribution to impaired SRV diastolic filling. These findings corroborate the previous evidence that patients with D-TGA/ASO have abnormal decrease in stroke volume during exercise whereas L-TGA patients can reach values comparably to healthy controls [2].

Abstract Figure 1

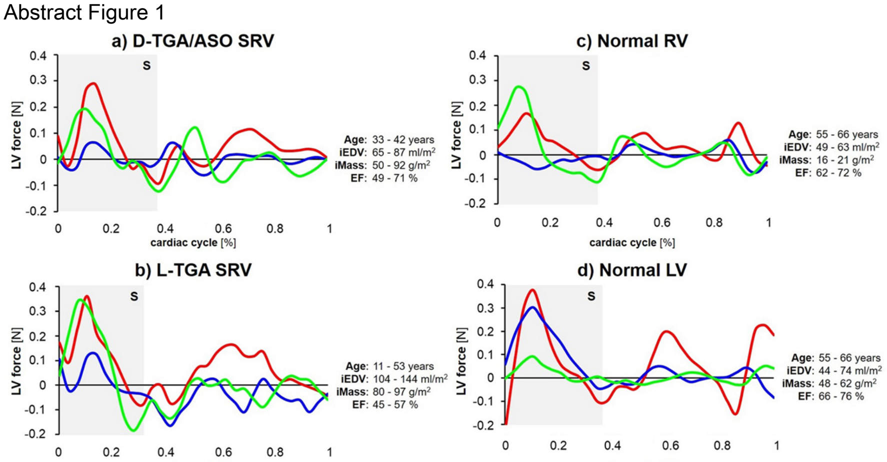

Figure 1. Hemodynamic forces time-curves and general features of the four analysed groups. Hemodynamic forces are projected onto three directions: inferior-anterior (IA), septal-lateral (SL) and basal-apical (BA). **iEDV**, indexed end-diastolic volume; **iMass**, indexed mass; **EF**, ejection fraction; **S**, systole.

Abstract Figure 2

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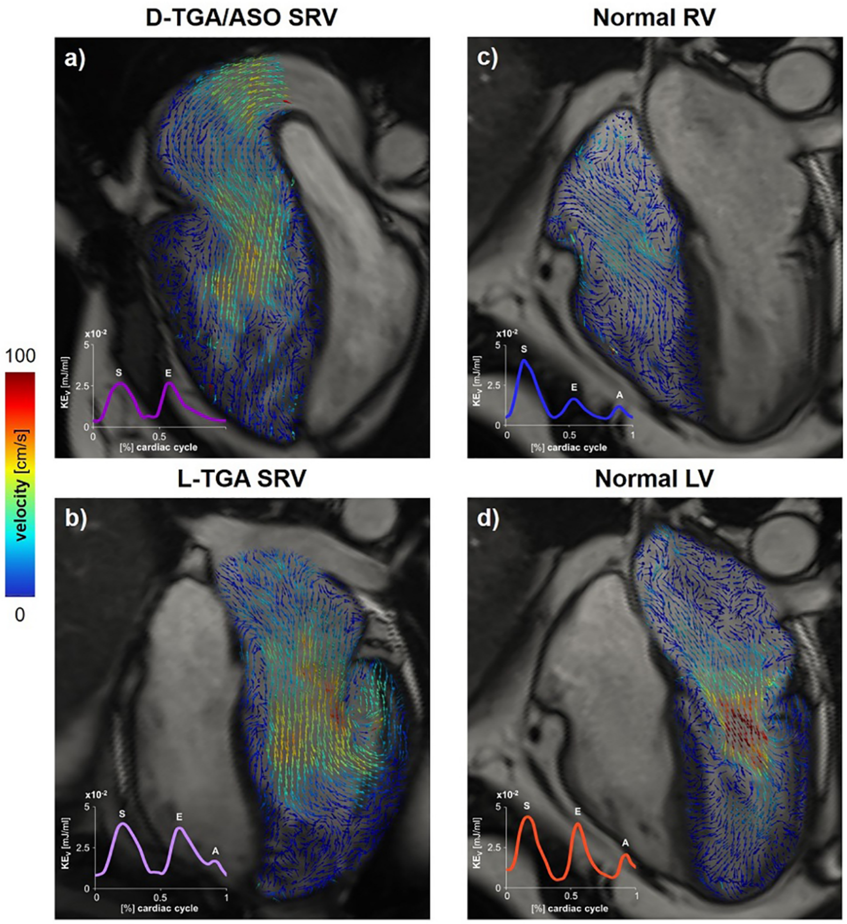

Figure 2. 4D Flow velocity vectors are displayed at peak E-wave for SRVs (**a**,**b**) and normal RV (**c**) and LV (**d**). Kinetic energy (KE) indexed to ventricular volume, curves are showed over the whole cardiac cycle for each group. **S**, systole; **E**, peak E-wave; **A**, peak A-wave

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