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Abnormal blood flow dynamics are associated with anatomical torsion of the aortic arch and eccentric geometry of the RV in Patients with Hypoplastic Left Heart Syndrome after three-stage palliation.

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Objectives: The reconstructed aortic arch of patients with Hypoplastic Left Heart Syndrome (HLHS) has an important impact for long-term prognosis. 4D Flow MRI allows determining a variety of novel fluid-dynamic parameters (e.g. helicity, circulation, vorticity in defined volumes of the vessel). Therefore, we thought to test the hypothesis that aortic arch geometry effects blood flow dynamics and may effect right ventricular function in HLHS.

Methods: Twenty-four HLHS patients (median age: 4.4; 2-17 years; all NYHA I) underwent a comprehensive MRI examinations including 4D-flow acquisitions 1.8 (0.4-14.1) years after completion of the Fontan circulation. Volumetric data were used to estimate right ventricular (RV) function. With an in-house analysis software (C++ based), novel parameters of blood flow dynamics were calculated within the cardiac cycle along the entire thoracic aorta from the neo-aortic valve towards diaphragm and were correlated with geometric parameters (such as geometric torsion which describes the twist of a curvature out of the plane) and parameters of the RV.

Results: Peak effective torsion (geometric torsion multiplied with curvature) of the neo-aortic root correlated significantly with peak helicity density of the blood flow ($p < 0.01$, adj. $R2 = 0.33$, $rho=0.59$). The peak relative helicity density correlated with the variation (difference between maximum and minimum) of the aortic diameters ($p=0.03$, adj. $R2=0.18$, $rho=0.46$) as well as with the maximum diameter of the aorta ($p=0.04$, adj. $R2=0.15$, $rho=0.44$). RV function (EF 57%±10%), volumes and mass did not correlate with any of the flow parameters. The mass-to-volume ratio, a parameter of eccentric geometric remodeling of the RV, correlated inversely with the peak helicity density ($p=0.05$, adj. $R2=0.14$, $rho=-0.43$).

Conclusion: Our data show that abnormal blood flow patterns in the thoracic aorta in HLHS after three-stage palliation are strongly associated with geometric torsion of the aortic arch, variations of the aortic diameters and eccentric RV geometry. Our findings may trigger modifications of surgical reconstruction to optimize fluid-dynamic conditions in the future.