Patients with corrected atrioventricular septal defect demonstrate regionally disturbed left ventricular inflow patterns with decreased LV ejection efficiency : a quantitative evaluation by 4DFlow MRI and particle tracing

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Purpose: The organization of blood flowing in and out of the left ventricle (LV) affects the efficiency of cardiac pumping performance. An altered inflow direction due to a corrected atrioventricular septal defect (AVSD) may disturb the normal blood flow pattern leading to decreased efficiency. We aimed to quantitatively describe LV blood flow patterns and evaluate LV ejection efficiency using 4-dimensional velocity-encoded cardiac magnetic resonance imaging (4DFlow MRI) and particle tracing in healthy volunteers and corrected AVSD patients.

Method: 32 patients (age 25±14 years) and 30 healthy volunteers (age 26±12 years) were included. Whole-heart 4DFlow MRI was performed on 3Tesla MRI with free breathing, three-directional velocity encoding of 150cm/s in all directions, spatial resolution 2.3×2.3×3.0-4.2mm^3 and 30 phases reconstructed over one cardiac cycle. At end-diastole the LV was evenly filled with particles which were subsequently tracked using the velocity-encoded data and backward (for diastolic inflow) and forward (for systolic outflow) particle tracing to analyze 4-componental LV flow as introduced by Eriksson [JCMR 2010] discriminating 1) direct flow entering and leaving the LV within one cycle, 2) retained flow entering during diastole but remaining in LV during next systole, 3) delayed ejected flow already present in LV before diastole and leaving LV during systole and 4) residual volume. Particles contributing to regurgitant flow in patients were labelled as a fifth component. The path of inflowing particles (i.e. direct and retained flow) during diastole was evaluated using the 16-segment LV cavity model based on standard model from American Heart Association. Differences in componental percentage and in particle percentage (pp; amount of particles per segment as percentage of the sum of particles) between patients and controls were compared using unpaired t-tests. Data was compared using a mixed model analysis.

Results: Patients showed a smaller percentage of direct flow compared to volunteers and larger percentage of delayed ejected flow and residual volume (Figure 1). Particle percentages reaching the mid ventricular (controls 58 ± 9% versus patients 68 ± 13%, p<0.001) and apical level (controls 14 ± 7% versus patients 23 ± 13%, p<0.001) were higher in patients. In controls direct flow, as percentage of total inflow, was higher in the basal level, especially in inferolateral and anterolateral segments (Figure 2). In contrast, the retained flow was higher in basal and mid inferolateral and anterolateral segments in patients (Figure 3). Direct flow into the apex was not significantly different between patients and controls, whereas retained inflow into the apex was significantly higher in patients (controls 7 ± 3% versus patients 14 ± 6%, p=0.005).

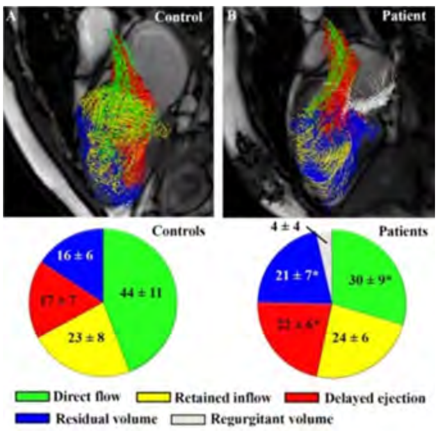

Figure 1: Example of a control (A) and patient (B) at an early systolic phase. Pie chart presents component percentage of left ventricular flow, with * indicating P<0.01.

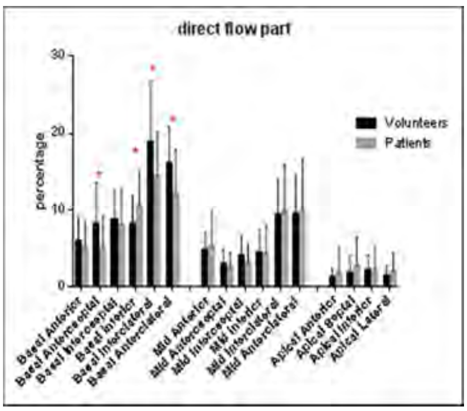

Figure 2: Direct inflow percentage divided over 16 segments. * Indicate difference between volunteers and patients with P<0.05.

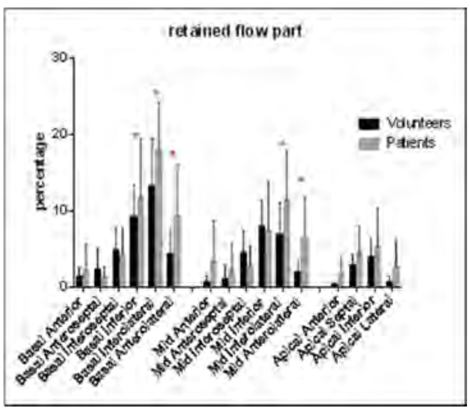

Figure 3: Retained inflow percentage divided over 16 segments. * Indicate difference between volunteers and patients with P<0.05.

Conclusion: Particle tracing and 4DFlow MRI can quantitatively demonstrate altered LV filling and ejection patterns after AVSD correction. Patients present more lateral and apical inflow, which results in decreased direct flow and increased retained flow percentage for apical and lateral LV cavity segments, which may contribute to a decreased cardiac pumping efficiency.