Segmental Tissue Phase Mapping analysis of biventricular heart function

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Target audience: researchers interested in biventricular functional analysis.

Purpose: Right ventricular function is an important prognostic factor for patients with pulmonary hypertension, congenital heart disease or heart failure [1]. As echocardiography is limited in the imaging of the right ventricle (RV), MRI is the gold standard for the analysis of global systolic RV function. Regional motion parameters of the RV, however, might be more sensitive for the detection of RV disease [2] and the inclusion of segmental RV function might improve resynchronization therapy [3]. In addition, right ventricular myocardial velocities as markers of regional myocardial contractility correlate well with ejection fraction in the healthy and diseased right ventricle [4] In contrast to MR tagging, which is limited in the imaging of the thin right ventricular walls due to the spatial restriction of the Tagging grids, phase contrast MRI offers high spatial and temporal resolution for this application. The aim of our study was to assess right ventricular velocities of all RV segments in healthy individuals using MR Tissue Phase Mapping (TPM).

Methods: 3 short-axis slices (base, mid, apex) in 10 healthy volunteers (age= 32±8years) were acquired with a 3T Trio system (Siemens). A black-blood prepared gradient echo sequence was used (temporal resolution 24.4 ms, spatial resolution 1.0×1.0×8 mm; *venc* [in-plane] = 15 cm/s, *venc* [through-plane] =25 cm/s, with prospective ECG gating and double navigator respiration control [5] and kt-accelerated PEAK-GRAPPA with an acceleration factor of R=5 [6]. To avoid saturation effects in the basal slice of the RV myocardium, the width between the two saturation bands of the black blood module had to be increased (from 24 to 28 mm) due to a more pronounced RV long-axis motion compared to the LV.

Data post-processing (Matlab) included eddy current correction, semi-automatic segmentation of the LV and RV and a transformation of the measured velocities (V_x,V_y,V_z) into perpendicular (V_r) and tangential (V_φ) to the inner heart wall in-plane velocities. For segmental analysis the left ventricle (LV) was divided according to the AHA 16-segment model and the RV in a self-defined 10-segment model (see Fig.1 & 3). For V_r and V_z, global (averaged over the entire slice, Fig. 2) and segmental systolic and diastolic peak velocities were derived.

Results: A synchronous motion between the right and left heart was revealed in all healthy volunteers (Fig. 1). Peak radial velocities (V_r) were higher in the basal and midventricular parts of the right ventricular free wall than in the left ventricle (in systole: mean: 3,8±1,0 cm/sec in the RV vs. 3,0±1,0 cm/sec in the LV, Fig. 2 and Fig. 3). Peak radial as well as long-axis velocities in the RV decreased from the RV free wall to the RV parts adjacent to the LV. Peak radial and long-axis velocities were lower in apical compared to basal parts of the RV (Fig. 3) in systole and diastole. Similar to the left ventricle RV velocities were highest in the base, in diastole and in long-axis direction. Maximal velocities were observed in the basal and midventricular infero-lateral segments of the RV free wall.

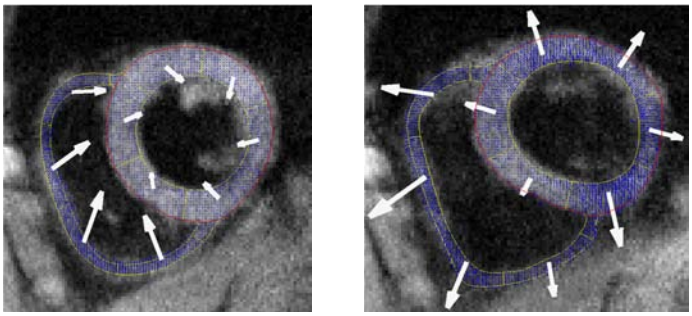

Fig. 1: Vector plots of the in-plane velocities of the left and right heart in a healthy volunteer in systole (left) and diastole (right).

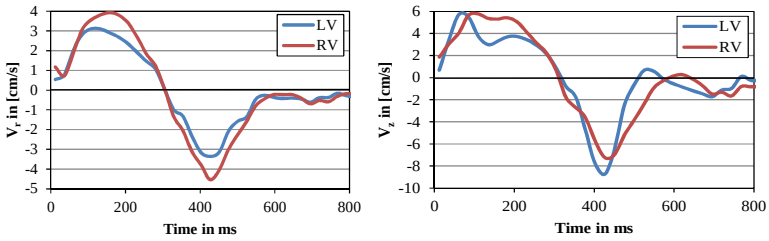

Fig.2: Comparison between velocity-time courses of global radial velocities (V_r, left) and of long-axis velocities (V_z, right) in the basal LV and RV averaged over all healthy volunteer.

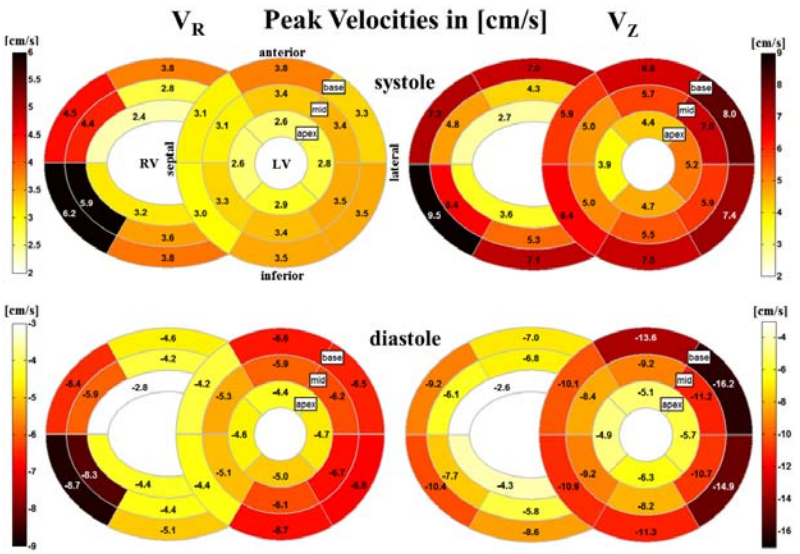

Fig. 3: Segmental peak radial (V_r) and long-axis velocities (V_z) in systole (upper row) and diastole (lower row) of the right and left ventricle.

Discussion: Using TPM, we could quantify regional RV function in the healthy right ventricle. The distribution of RV myocardial velocities is heterogeneous with a gradient between base and apex and between the RV free wall and the segments attached to the septum. In line with literature we demonstrated highest velocities in the long-axis direction of the RV [7]. A similar distribution of RV radial velocities was described compared to our findings, however only a midventricular RV location was imaged [7]. A second study using phase contrast MRI for RV function analysis revealed a good correlation of MRI with tissue Doppler imaging and reduced long-axis velocities in two RV segments in children with corrected tetralogy of Fallot [8]. So far, no comprehensive evaluation of segmental RV velocities of the complete RV has been published.

Conclusions: TPM enables a comprehensive analysis of RV motion and might help to improve the patient management with RV disease or heart failure. Further studies with an increased number of volunteers and patients including a comparison to conventional methods (e.g. Speckle Tracking echocardiography) have to be performed.

References: [1] Apostolakis S et al. Cardiology 2012;121:263–273 [2] Teske AJ et al. J Am Soc Echocardiogr 2009; 22(8): 920-7. [3] Vitarelli A et al. J Card Fail 2011; 17(5): 392-402. [4] Wang J et al. J Am Soc Echocardiogr 2007; 20(9): 1058-64. [5] Jung et al. Magn Reson Med 2006;55:937-942. [6] Jung et al. Magn Reson Med 2008; 60:1169-77. [7] Kayser HW et al., J Magn Reson Imaging 2000; 11(5): 471-5. [8] van der Hulst AE et al. Radiology 2011; 260(1): 88-97.

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