Tissue Phase Mapping Using Single Breath-hold 4D PCMR

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Background: Magnetic resonance tissue phase mapping (TPM) allows assessment of the separate directional components of wall motion, as well as their regional distribution. Conventionally TPM is carried out in one 2D slice in the left ventricle (LV). However, acquisition of the 3D motion field over the entire left ventricle would allow a more detailed understanding of the motion patterns. 4D PCMR has not previously been used for TPM due to long acquisition times. The purpose of this study was to develop a highly accelerated 4D PCMR sequence to acquire TPM data across the entire left ventricle, during a single breath-hold.
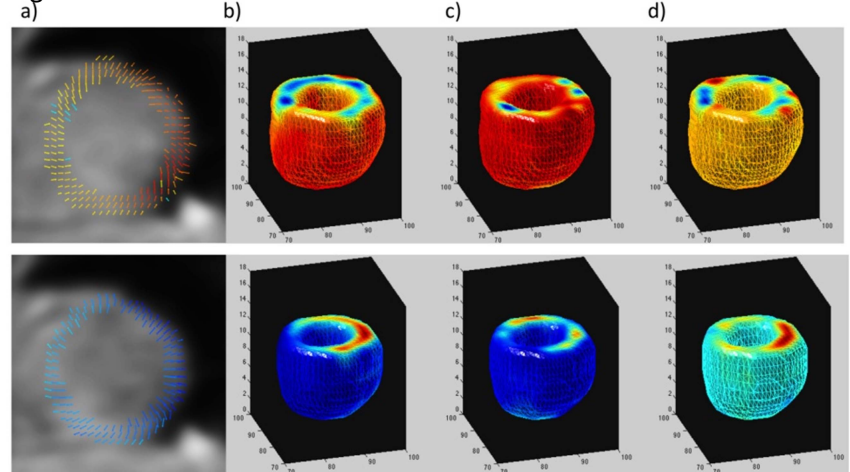
Methods: An undersampled, prospectively triggered, stack-of-spirals, 4D PCMR sequence was developed, and reconstructed using SENSE-UNFOLD. A uniform-density spiral trajectory was used in kx-ky with 8 interleaves required to fill k-space, with acceleration of R=4 (resulting in 2 spiral interleaves acquired per kz position). In kz, 16 slices were used, with acceleration of R=2, resulting in 9 kz positions being acquired for each cardiac phase (calculated as 16÷2 plus one to ensure that the middle kz position is always acquired). The other sequence parameters were; TE/TR: 4.0/14.4ms, matrix size: 160x160, FOV: 500x500mm, slices: 16, slice thickness: 8mm, venc(x/y/z): 30/30/30cm/s. This resulted in a temporal resolution of 57.5ms, a spatial resolution of 3.1x3.1x8mm, and a scan time of 16 heartbeats (single breath-hold), plus 7.3s for acquisition of fully sampled coil sensitivity maps

Fig.1:

Example data from a healthy volunteer. Top; peak *S* wave, bottom; peak *E* wave. a) 2D vector plots from the mid slice, b) Longitudinal velocity, c) Radial velocity, d) Tangential velocity. The colors represent the velocities, with reds representing shortening/contraction/clockwise rotation, and blues representing lengthening/expansion/counter-clockwise rotation.

with 4NSAs (free breathing, at the end of the TPM acquisition). This 4D PCMR TPM data was acquired in 5 healthy volunteers (4M:1F, mean age:38.6±6.6yrs), and 1 patient with mild LV dyssynchrony (F, 43.3yrs).

Data Analysis: Bulk motion correction was performed, before transformation of the velocities to an internal polar coordinate system allowing motion to be described in terms of contraction (using radial velocities; V_r) and shortening (using longitudinal velocities; V_z). Peak velocities in the S (systolic) and E (early diastolic) waves were measured for the longitudinal and radial velocities within the entire myocardium, at a basal, mid and apical slice.

Results: Data was successfully acquired and analyzed in all subjects. Figure 1 shows the calculated velocity data in one subject. In the volunteers quantitatively, the longitudinal velocities in the base/mid/apical slices were 4.9±1.2/3.5±1.3/2.4±0.6 cm/s at the *S* wave, and -6.2±1.3/-3.9±1.4/-2.43±1.5 cm/s at the *E* wave. The radial velocities in the base/mid/apical slices were 2.2±0.4/2.7±0.2/ 2.1±0.2 cm/s at the *S* wave, and -2.5±0.4/ -3.1±0.5/-2.9±0.1 cm/s at the *E* wave. In the patient the longitudinal velocities in the base/mid/apical slices were significantly lower at the *S* wave (1.1/1.0/1.4 cm/s). Furthermore,

Fig.2:

Data from the patient showing an area of the septum with a subtle dyssynchrony. a) Longitudinal velocity, b) Radial velocity, c) Tangential velocity.

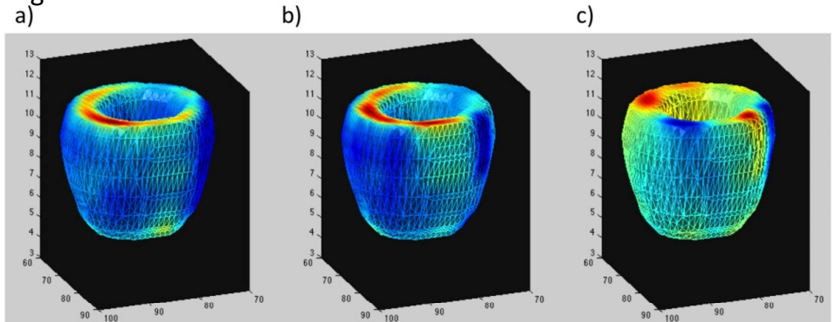there was evidence of dyssynchrony in early LV diastole as shown in figure 2.

Conclusions: We have shown that using a novel spiral UNFOLD SENSE PCMR sequence it is possible to obtain 4D TPM data in a single breath hold. This sequence may have significant value in the assessment of LV dyssynchrony, particularly in relation to resynchronization therapy.