Navigator Gated High Temporal Resolution Tissue Phase Mapping of Myocardial Motion

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Introduction: Established methods for quantification of myocardial wall motion are tagging, phase contrast velocity mapping (tissue phase mapping, TPM) and DENSE. Data acquisition with these methods is typically based on multiple breath-held (BH) 2D measurements. A major drawback is related to limited spatial and temporal resolution due to the length of the breath-hold period. In order to overcome these limitations an improved navigator-guided technique for the acquisition of TPM data during free-breathing (FB) was implemented [1] and compared to standard BH measurements.

Methods: Improved navigator gating was performed using two navigators per cardiac cycle in combination with real-time acceptance criteria based on signal from successive navigator echo pairs, in the center and at the end of the cardiac cycle (see Fig.1). Breathing motion could lead to falsified velocities with the use of one navigator per cardiac cycle due to the low measured velocities in the myocardium. The time for thew navigator echoes and its evaluation was 40 ms per cardiac cycle. Data was accepted within a 6-mm acceptance window in end-expiration.

All measurements were performed on a 1.5 T Magnetom Sonata (Siemens, Germany). TPM images were acquired with a black blood k-space segmented gradient echo sequence (TR = 6.9 ms) with first-order flow compensation. The pixel size was 1.3 x 1.3 mm (96 x 256 matrix interpolated to 192 x 256). Velocity encoding was performed with a *venc* of 15 cm/s for in-plane and 25 cm/s for through-plane encoding. A temporal resolution of 13.8 ms was achieved by the use of view sharing technique. Reference and motion-sensitized scans were performed sequentially, since an interleaved velocity encoding order limits the minimal temporal resolution to 4*TR=27.6 ms without the posibility of view-sharing. Three slices (8 mm thickness) in short axis view (basal, midventricular, apical) were acquired in 12 healthy volunteers (mean age 32 y). The mean scan efficiency over all acquired slices was 43 % leading to an acquisition duration of about 4½ minutes per slice. For comparison TPM images were acquired during breath-hold period of 25 heartbeats with a temporal resolution of 69 ms.

Data postprocessing was performed using customized software programmed in Matlab (The Mathworks). After contour segmentation and a correction for translational motion components of the LV, the measured in-plane velocities were transformed into an internal polar coordinate system positioned at the center of mass of the left ventricle. As a result, motional parameters are decribed in terms of radial, tangential and longitudinal velocities leading to a more adapted representation of the myocardial motion. To avoid temporal jitter, the temporal axis was normalized to the end-systolic time as defined by the first minimum peak of the global radial velocities during diastole (see Fig. 1) which could be observed in all volunteer measurements. A paired t-test of radial systoic and diastolic peak velocities between the low and high temporal resolution time courses was performed.

Results: Fig. 1 shows the time courses of radial velocities in a basal slice with a temporal resolution of 69 ms (BH; A) and 13.8 ms (FB; B) revealing more complex motion patterns including additional peaks during diastole (B). Color-coded maps of radial velocities in time frames for diastolic peak velocities show an early expansion in the anteroseptal wall and a delayed expansion of the septal wall. This LV expansion pattern was observed in all volunteers. Fig. 2 shows the global radial velocities over the cardiac cycle in basal slice for breath-hold (A; 69 ms) and free-breathing (B; 13.8 ms) acquisition averaged over all volunteers. The error bars give the interindividuel standard deviations of the measured volunteers. Mean radial peak velocities during systole (Vr,sys) and diastole (Vr,dia) for the BH and the FB measurements in each slice are summarized in table 1. Differences of systolic peak velocities were not significant ($p>0.05$), whereas diastolic peak velocities were significantly higher ($p<0.01$) for high temporal resolution for all slices.

Discussion: An efficient strategy was presented for the combination of TPM acquisition and navigator based respiratory gating that allows TPM data acquisition with high temporal resolution. The detailed motion patterns obtained with our high resolution TPM implementation are only known from echocardio-graphic measurements [2] and could be used to detect motion abnormalities, e.g. in patients with diastolic dysfunction. Scan time may be reduced by the use of a motion-adapted gating technique [3] or radial acquisition strategies with interleaved undersampled projections [4]. Additional scan time reduction while maintaining SNR might be feasible by the use of parallel imaging techniques at higher field strength.

References: [1] Jung et al. *Proc. SCMR* 2005; p193. [2] De Boeck et al. *Am Heart J* 2003; 146:411-19. [3] Weiger et al. *MRM* 2005; 53:177-85. [4] Barger et al. *MRM* 2000; 43:503-509.

Slice	Basal		Medial		Apical	
T. res [ms]	69	13.8	69	13.8	69	13.8
$V_{r,sys}$ [cm/s]	2.62 ± 0.49	2.56 ± 0.32	2.77 ± 0.62	2.55 ± 0.35	2.02 ± 0.48	1.96 ± 0.27
Paired t-test	ns (p=0.30)		ns (p=0.08)		ns (p=0.31)	
$V_{r,dia}$ [cm/s]	-2.78 ± 1.08	-4.00 ± 0.75	-3.46 ± 0.97	-4.33 ± 0.79	-2.87 ± 0.60	-3.80 ± 0.89
Paired t-test	s (p=0.0007)		s (p=0.0077)		s (p=0.0046)	

Table 1: Mean radial peak velocities ± standard deviation during systole (Vr,sys) and diastole (Vr,dia) for breath-hold (69 ms) and free-breathing (13.8 ms) acquisitions in each slice.

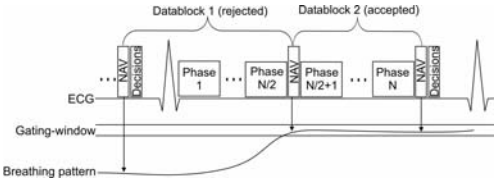

Fig. 1: Acquisition strategy for the navigator-gated free-breathing measurements. The situation is represented when datablock 1 is rejected and datablock 2 accepted.

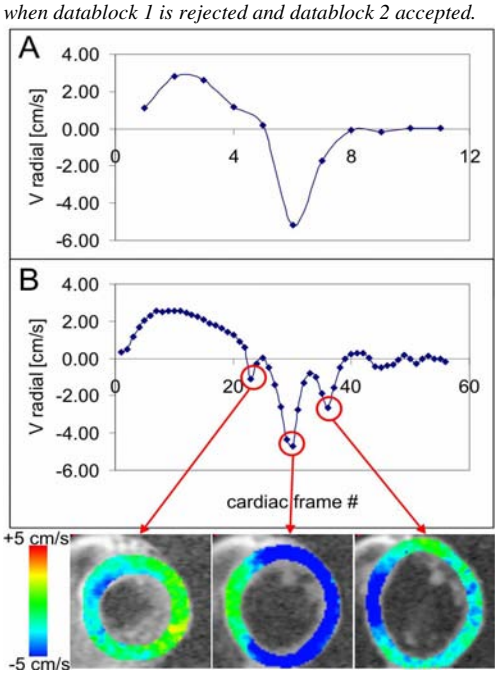

Fig.2: Global radial velocities over the cardiac cycle in a basal slice of a volunteer for the BH (A; 69 ms) and FB (B; 13.8 ms) acquisition.Colorcoded maps of radial velocities are depicted (red=contraction; blue= expansion) for the three peaks during diastole in (B).

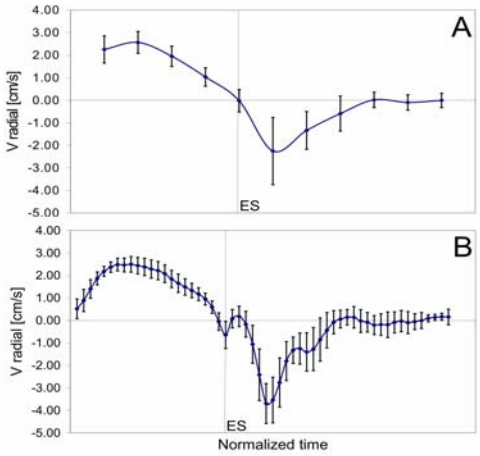

Fig.3: Global radial velocities over the cardiac cycle in basal slice for breath-hold (A; 69 ms) and free-breathing (B; 13.8 ms) acquisition averaged over all volunteers (ES=end-systole).