Impact of temporal resolution on the quantification of regional myocardial velocities using tissue phase mapping

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Target audience: Radiologists, cardiologists and MRI researchers

Purpose: Tissue phase mapping (TPM) can measure and detect abnormal myocardial motion, a manifestation of various ischemic or non-ischemic heart diseases (1-3). Generally, 2D TPM acquires time-resolved (CINE) magnitude images and three-directionally velocity encoded phase difference images (vx,vy,vz) during a single breath holding (4, 5). Fail to hold the breath may result in poor image quality for clinical use. Although many technical advances, such as *k-t* parallel imaging PEAK GRAPPA, has been applied for imaging acceleration to shorten the breath holding duration, a breath hold (> 20 seconds) still seems too long to some of examinees. In theory, lowering temporal resolution of TPM may result in a shortened image acquisition time. However, such an adjustment can result in the loss of some useful diagnostic information carried by images. Therefore, the aim of this study is to assess the impact of temporal resolution on different breath-hold duration on regional LV velocities and test the hypothesis that higher temporal resolution can result in less temporal filtering and thus higher peak velocities.

Materials and Methods: With the approval of IRB, 7 healthy volunteers underwent cardiac MRI scans for the evaluation of regional cardiac motion. See figure 1 for the description of our subjects. TPM data were acquired in basal, midventricular and apical locations at left ventricle (LV) using a black-blood prepared cine phase-contrast sequence with tri-directional phase encoding in the short axis orientation (venc=25cm/sec, temporal resolution=24msec, spatial resolution=2.0 x 2.0mm^2, slice thickness=8mm). For each participant, TPM images were acquired at high (20.8ms/cardiac time frame, breath hold duration = 25 heart beats) and lower (38.4ms/cardiac time frame, breath hold duration = 14 heart beats) temporal resolution. Spatio-temporal imaging acceleration (k-t parallel imaging PEAK GRAPPA) with a net acceleration factor of Rnet = 3.6 was employed which permitted data acquisition during breath-holding (breath-hold time = 25 heart beats per slice). Analysis included manual segmentation of the LV contours by an experienced reader and transformation of the acquired tri-directional velocities into radial velocities representing contraction and expansion in the short axis and long-axis velocities. Time-resolved radial, and long-axis velocities were acquired using TPM in basal, midventricular, and apical short axis slices. Long-axis velocities were orthogonal to the short axis imaging plane. Velocities were defined as positive for systolic contraction / shortening. As shown in figure 1, the resulting velocity components thus describe the myocardial velocities along the axes of the LV. Radial and long-axis velocities were mapped onto the AHA 16-segment model by averaging velocities for all voxels within each myocardial segment. For all 16 segments, peak systolic and diastolic radial and long-axis velocities were extracted. In addition, global LV systolic and diastolic peak radial and long-axis velocities were calculated for each subject as the average over all 16 segments. The myocardial indices (on each slice) acquired with two protocols were compared using *t*-tests.

Male (%)	**4 (57)**
Age (years old)	49.4 ± 20.5
Weight (kg)	88.1 ± 20.5
Height (cm)	171.2 ± 10.9
Heart rate before the scan (beats/minute)	64.7 ± 9.1
Heart rate after the scan (beats/minute)	64.8 ± 10.6
SBP before the scan (mmHg)	126.1 ± 22.1
DBP before the scan (mmHg)	75.2 ± 24.8
SBP after the scan	124.6 ± 28.1
DBP after the scan	74.6 ± 24.3

Table 1 Subject information

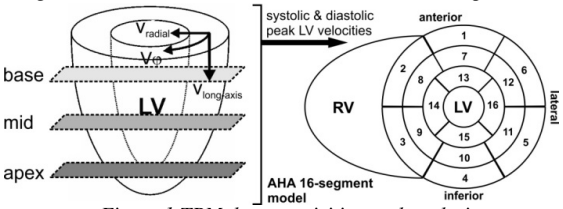

Figure 1 TPM data acquisition and analysis strategy

Results: All 7 scans were successfully completed and all images were eligible for quantitative analysis. The TPM with a low temporal resolution (38.4ms) required shorter scan time (breath hold) than TPM with a high temporal resolution (20.8ms) (11.8 ± 0.1 seconds vs. 23.2 ± 0.2 seconds, $p < 0.05$). Figure 2 shows a side-by-side comparison of LV velocity-time curves from TPM scans with high vs. lower temporal resolution. Figure 3 shows the distribution of peak systolic radial and long-axis myocardial velocities in the AHA 16-segment model. There are good agreements of the radial (v_r), circumferential (v_Φ), and long-axis (v_z) velocities in different LV locations (base, mid and apex) between two schemes. Table 2 shows mean systolic and diastolic v_r and v_z velocities of LV at basal, mid-ventricular, and apical levels.

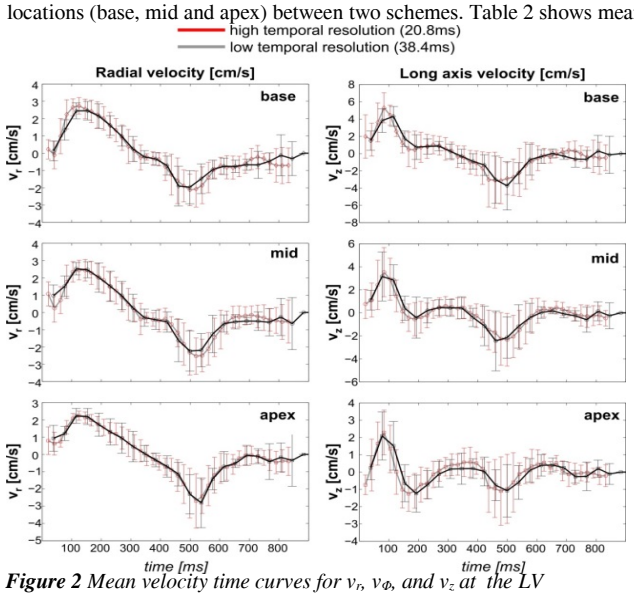

Figure 2 Mean velocity time curves for v_r, v_Φ, and v_z at the LV (base, mid, and apex). The standard deviations indicate differences in LV velocities between the 7 subjects.

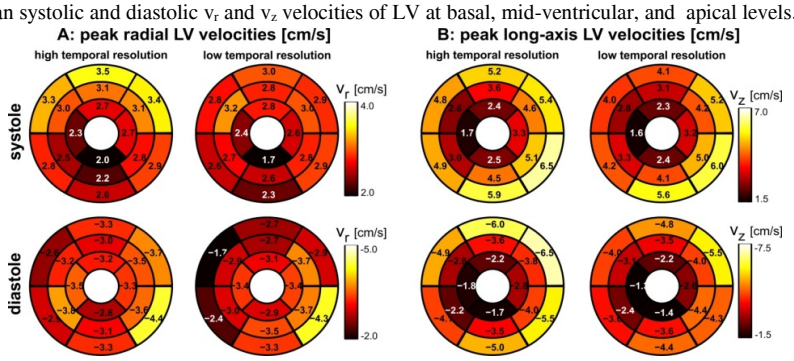

Figure 3 *Systolic and diastolic peak radial LV velocities (A) and peak long-axis velocities (B) for high and low temporal resolution TPM. The value of each segments corresponds to the average peak velocity over 7 normal subjects.*

SAX	systolic peak vr [cm/s]		diastolic peak vr [cm/s]		systolic peak vz [cm/s]		diastolic peak vz [cm/s]	
location	high res.	low res.	high res.	low res.	high res.	low res.	high res.	low res.
base	**3.1 ± 0.6***	**2.7 ± 0.6**	-3.5 ± 1.3	-3.2 ± 0.8	5.5 ± 1.7	4.8 ± 1.2	-5.4 ± 2.7	-4.8 ± 2.4
mid	2.8 ± 0.6	2.9 ± 0.5	-3.5 ± 1.2	-3.6 ± 1.0	3.9 ± 1,9	3.8 ± 1.9	-3.5 ± 2.7	-3.9 ± 2.1
apex	2.4 ± 0.3	2.4 ± 0.5	-3.1 ± 1.3	-3.5 ± 1.1	2.5± 1.2	2.4 ± 1.3	-2.3 ± 1.6	-2.1 ± 1.3

Table 2 *For each LV velocity component, the table shows side-by-side comparisons of TPM scans with high vs. lower temporal resolution. All numbers represent mean velocities over all 7 subjects. * indicates significant differences (paired t-test, p<0.05).*

Discussion: In the present study, we demonstrated that acquiring TPM at a low temporal resolution (with a short scan time) provide comparable cardiac indices to those results acquired with high temporal resolution (with a longer scan time). Nevertheless, we noticed significantly higher v_r ($p < 0.05$) at the base level measured with a high temporal resolution. Further studies are needed to resolve those differences using "gold standards" as references.

Conclusion: TPM with a low temporal resolution requires a shorter breath hold but keeps similar diagnostic information regarding LV motion. Such a scheme may serve as an alternative in clinical study for those subjects who cannot hold breath for a long time.

References: 1. Jung B, et al. *J Magn Reson Imaging*. 2006;24:1033-1039 2.Petersen SE, et al. *Radiology*. 2006;238:816-826 3. Delfino JG, et al. *Radiology*. 2008;246:917-925 4. Foll D, et al. *Circ Cardiovasc Imaging*. 2010;3:54-64 5. Jung B, et al. *Magn Reson Med*. 2008;60:1169-1177

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