

# Detailed Analysis of Myocardial Motion in Volunteers and Patients using High Temporal Resolution MR Tissue Phase Mapping

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**Introduction:** Since diastolic dysfunction accounts for up to one half of the cases of heart failure, abnormal regional left ventricular wall motion is an important clinical marker in multiple cardiac pathologies [1]. Tissue Doppler imaging (TDI) is an established method allowing for the investigation of regional myocardial motion with high temporal resolution [2]. Drawbacks of TDI are related to limitations of the acoustic window and the dependance of myocardial velocities on the angle of insonation. In order to overcome limitations of TDI, respiratory gated MR tissue phase mapping (TPM) measurements with high temporal resolution comparable to TDI were performed in 12 volunteers and 2 patients with LV hypertrophy and characteristic findings in myocardial motion were discussed.

**Methods:** Advanced navigator gating was performed using two navigator echoes per cardiac cycle in combination with real-time acceptance criteria based on signal from successive navigator echo pairs, in the middle and at the end of the cardiac cycle, as recently described [3]. The total time per cardiac cycle for the navigators and its evaluation was 40 ms. Data acceptance was inside 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 prospective ECG-gating and 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 *vec* 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. Three slices (8 mm thickness) in short axis view (basal, medial, apical) were acquired in 12 volunteers (mean age 32 y) and 2 patients with LV hypertrophy (mean age 38 y). The mean scan efficiency over all acquired slices was 43 % leading to an acquisition duration of about 4½ minutes per slice. In order to compare the velocity time courses obtained by MRI, TDI measurements were performed in one healthy subject with a standard ultrasound machine (GE, Vivid 7). Data from regional myocardial velocity profiles of the longitudinal component were acquired in an anteroseptal region with a temporal resolution of 9.5 ms and compared to a corresponding regional analysis of the same volunteer.

TPM data postprocessing was performed using customized software programmed in Matlab (The Mathworks). After contour segmentation and a correction for translational motion components, 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, motion parameters are described in terms of radial, circumferential 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 2) that could be observed in all measurements.

**Results:** Fig 1 shows magnitude images, color-coded maps of radial velocities (red: positive, contraction; blue: negative, expansion) in a basal slice for cardiac frames during mid-systole (a) and mid-diastole (b). Fig 2 shows the averaged time courses over all volunteers of radial (a) and longitudinal (b) velocities in all acquired slice locations. A small bi-phasic pattern during early diastole is clearly visible in all slices (arrow 1). Furthermore, the basal slice shows a tri-phasic diastolic expansion indicated by a third negative peak in the later diastole (arrow 2). Fig 3 shows the evolution of regional radial velocities (a) averaged over all volunteers in the 6 basal ROIs depicted in (b) according to the 16-segment model [4] revealing highly complex motion patterns during diastole. Fig 4 shows a comparison of regional longitudinal time courses between TDI (yellow) and TPM (blue) acquired in a healthy volunteer. Complex motion patterns such as the small biphasic wave of brief duration during isovolumetric relaxation (IVR) in early diastole are clearly visible in both measurements. Fig 5 shows the time courses of basal global longitudinal velocities in a patient with LV hypertrophy (blue) and averaged over all healthy volunteers (yellow) drawn in the same graph. The motion pattern during early diastole in the patient is prolonged and the peak velocities and the small bi-phasic pattern during early diastole are strongly reduced.

**Discussion:** The myocardial velocities of presented measurements in volunteers and patients show the potential to provide valuable information in the evaluation of global and regional function in cardiac pathologies. TPM measurements reveal LV dynamics that are only known from TDI measurements such as the small biphasic wave during IVR. The use of a retrospective ECG-gating technique would also allow for detection of the A-wave and the IVC phase (see Fig 4).

**References:** [1] Vasan et al. *Circulation* 2000; 101:2118-21. [2] De Boeck et al. *Am Heart J* 2003;146:411-19. [3] Jung et al. *Proc. ISMRM* 2005; p 1642. [4] Cerqueira et al. *Circulation* 2002; 105:539-42.

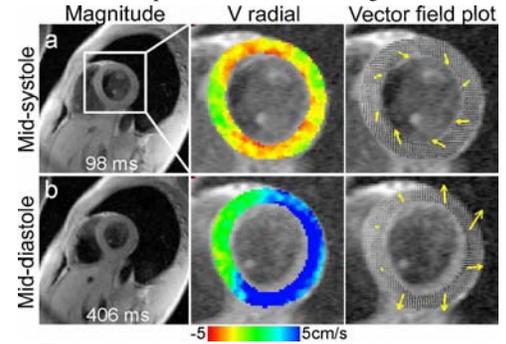


Fig.1: Magnitude images, color-coded maps of radial velocities and pixelwise arrow plots of in-plane velocities: a) mid-systole, b) mid-diastole.

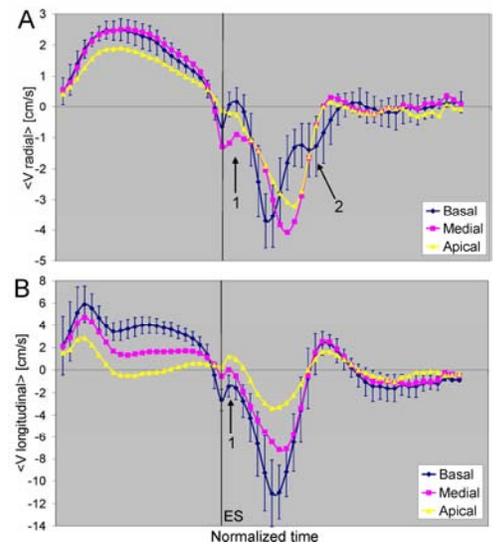


Fig.2: Time courses of radial (A) and longitudinal (B) velocities for basal, midventricular and apical slice locations averaged over all volunteers.

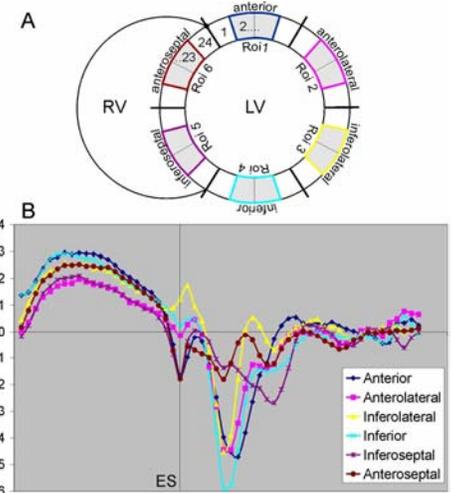


Fig.3: ROI analysis in 6 segments of a basal slice (A) with corresponding time courses of radial velocities averaged over all volunteers (B).

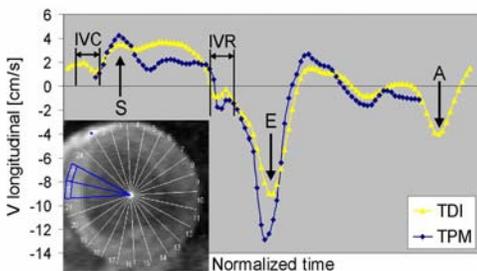


Fig. 4. Comparison of regional longitudinal velocities in a midventricular anteroseptal area measured by TDI (yellow) and TPM (blue) in the same volunteer.

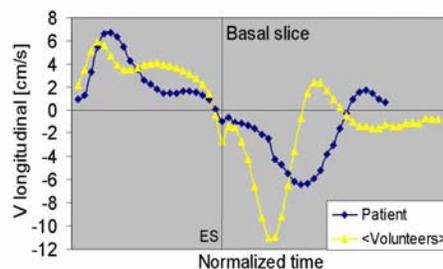


Fig.5. Global time courses of longitudinal velocities in basal slice in a patient with LV hypertrophy (blue) and averaged over all volunteers (yellow).