Left Ventricular Dyssynchrony: Effect of Age, Ejection Fraction, Mass and Cardiovascular Disease

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Introduction: The investigation of the coordinated mechanical cardiac function, i.e. the intraventricular synchrony of different LV segments, has gained increased importance as a prognostic marker in cardiac disease[1]. Dyssynchrony is associated with a worse outcome in patients with dilated cardiomyopathy (DCM), especially in the presence of a left bundle branch block (LBBB)[2]. In patients with hypertensive heart disease dyssynchrony is associated with reduced stroke volume, LVEF[2] and an increase in arrhythmias[3]. So far, the diagnosis of dyssynchrony is based on a variety of echo-based parameters, but it remains unclear, which myocardial velocity component is optimal for the detection of LV asynchrony, as a systematic analysis including all velocity components is missing. The aim of this study was to employ MR tissue phase mapping (TPM) for a comprehensive assessment of myocardial dyssynchrony. In contrast to previous studies, the analysis included the assessment of systolic and diastolic dyssynchrony along both the radial and long-axis motion direction. As a result, four different estimates of LV dyssynchrony were obtained and evaluated in a group of healthy controls (n=58). In addition, the sensitivity of the dyssynchrony measures to detect changes in patients (n=37) with left ventricular pathologies was investigated and compared to an age- matched control population.

Methods: TPM was performed on a 1.5T MR system (Sonata, Siemens, Germany) and consisted of a black blood prepared CINE GRE sequence with three-directional motion encoding (venc =15cm/s in-plane, 25cm/s through-plane). Data were acquired during free breathing (dual navigator gating) with view sharing and segmental velocity encoding resulting in a temporal resolution of 13.8ms. Further imaging parameters were: TE = 5.0ms, TR=6.9ms, flip angle=15°, in-plane spatial resolution = 1.3×2.6mm2, slice thickness = 8mm. TPM was employed to measure myocardial velocities along radial (v_{radial}) and long-axis ($v_{long-axis}$) directions in basal, midventricular, and apical short-axis slices in 58 normal controls (3 age-groups: <40years, 40-60years, > 60 years) and 37 patients (hypertensive heart disease, n=18, DCM, n=12, DCM & LBBB n = 7). Regional times-to-peak systole (TTP_{Sys}) and diastole (TTP_{Dia}) were derived from the temporal evolution of regional myocardial velocities for the entire LV using the standard AHA 16-segment model. Four different measures of LV dyssynchrony were defined as the standard deviation (SD) of systolic and diastolic TTP for both radial (v_{radial}) and long-axis ($v_{long-axis}$) motion (figure 1). Multiple linear regressions were used to model the relationship between the four dyssynchrony parameters and age, heart rate, LV ejection fraction, and LV mass as independent predictors. The relative contributions of the geometric predictors were determined from the standardized regression coefficients β.

Results: A significant relationship (r=0.49, p<0.001) between the LV dyssynchrony parameters and the maximum septal to lateral wall time delay as an established index for LV dyssynchrony confirmed the validity of the SD of the TTP velocities. As shown in figure 2, the presence of disease clearly altered myocardial dyssynchrony. During systole, a significant increase of radial dyssynchrony was observed for all patient groups compared to healthy controls, while long-axis dyssynchrony did not exhibit clear differences. During diastole, both radial and long-axis dyssynchrony demonstrated significant increases for DCM patients and all three patient groups, respectively. A gradual increase of dyssynchrony was observed from healthy controls to patients with hypertensive heart disease (hypertrophy) and further to patients with DCM. As expected the most prominent changes in myocardial dyssynchrony were seen in patients with DCM and LBBB.
Multiple regression analysis revealed that the combination of LV ejection fraction and LV mass was a strong predictor for impaired systolic and diastolic radial dyssynchrony as well as diastolic long-axis dyssynchrony. There was a significant (p<0.01) inverse relationship of dyssynchrony with LV EF (β = [-0.34,-0.62]) and a significant (p < 0.05) positive relationship with LV mass (β = [0.20, 0.34]) for all three dyssynchrony parameters. Further, diastolic LV dyssynchrony significantly (p<0.03) increased with age (β = [0.21, 0.45]), irrespective of the choice of myocardial motion component. Interestingly, systolic dyssynchrony based on long-axis velocities did not reveal a significant correlation with any of the analyzed independent predictors despite its use in a number of previous studies.

Discussion: The complete assessment of three-directional myocardial motion by TPM can provide measures for systolic and diastolic LV dyssynchrony for different motion components. These parameters are sensitive markers for the presence of cardiac disease typically associated with a reduction in coordinated LV function. Both radial systolic and long-axis diastolic myocardial dyssynchrony seem clearly superior to systolic long-axis synchrony as diagnostic markers for an altered timing in dilated cardiomyopathy and hypertensive heart disease. Long-axis systolic parameters did not discriminate the healthy from the diseased heart. This might be one of the reasons, why there is no optimal echo parameter for the patient`s selection for resynchronization therapy (CRT) so far[4]. Echocardiography does not enable the comprehensive evaluation of radial velocities in all LV segments. Therefore long-axis velocities have been preferred for multi-segmental analysis, whereas parameters of radial contraction included only few myocardial segments. The application of new imaging techniques as TPM might help to use CRT more efficiently.

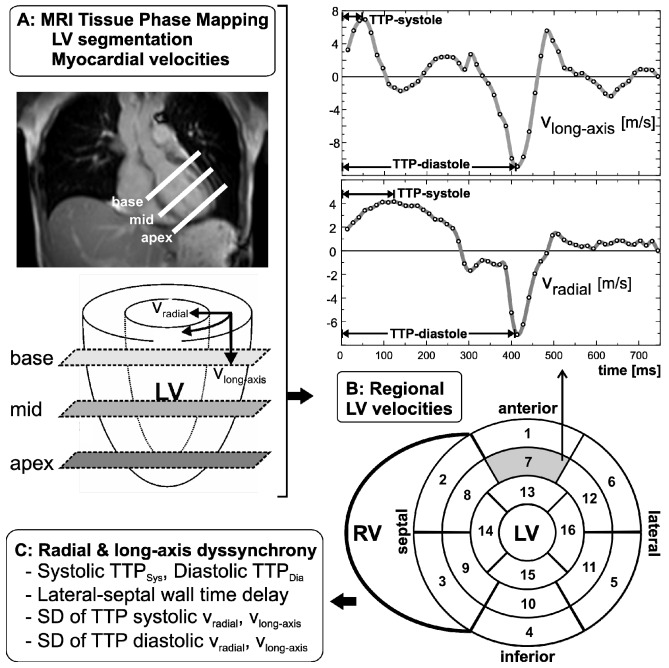

Fig. 1: ***A:*** *Time-resolved radial (v_{radial}) and long-axis ($v_{long-axis}$) velocities were acquired using TPM in basal, midventricular, and apical short axis slices.* ***B:*** *Data for each subject were mapped onto an AHA 16-segment model. For each segment, the velocity time courses were used to derive systolic (TTP_{Sys}) and diastolic (TTP_{Dia}) times-to-peak velocity as illustrated for radial and long-axis velocities.* ***C:*** *Systolic and diastolic dyssynchrony was assessed by calculating the standard deviation (SD) of radial and long-axis TTP over all 16 segments.*

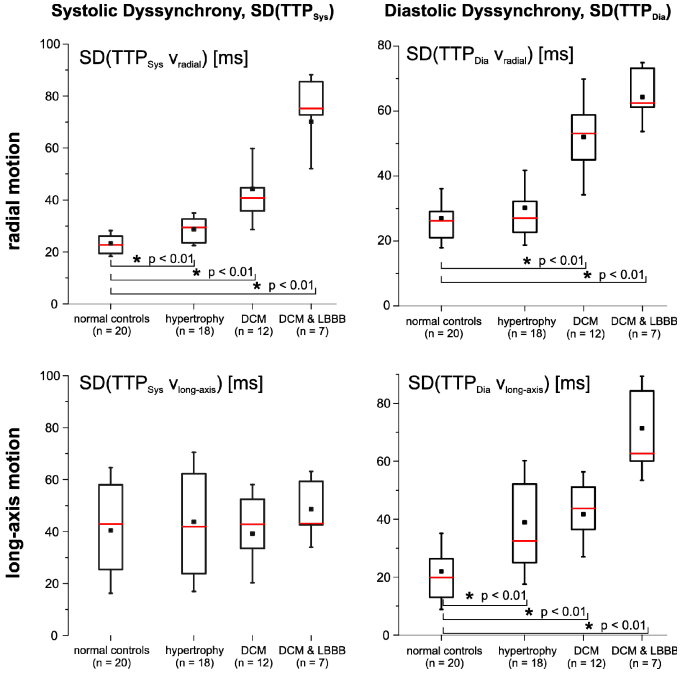

Fig. 2: *Systolic (top) and diastolic (bottom) left ventricular dyssynchrony in patients compared to age-matched healthy controls. (* indicates significant differences). Bar plots: mean (black filled rectangle), median (red line), standard deviation (error bars), [25% 75%] data range (open rectangles).*

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References: [1] Shamim W et al., Int J Cardiol 1999;70:171-8; [2] Sanderson JE , JACC 2007;49:106-108; [3] Tan HW et al. ,Hypertens Res 2007; 30: 759–766; [4] Chung et al. Circ 117: 2608-16