Accelerated 3D Tagging for Quantification of Left Ventricular Dyssynchrony in Patients after Myocardial Infarction

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Introduction: Cardiac resynchronization therapy (CRT) has proved successful in larger patient populations as an adjunctive therapy for patients with drug-refractory heart failure and ventricular conduction delay. However, individual responsiveness to CRT is not yet highly predictable. Around 30% of patients do not appear to benefit from CRT [1]. This can either be attributed to inappropriate patient selection or to suboptimal application of therapy. Accurate quantification of regional motion patterns and left ventricular (LV) dyssynchrony can improve discrimination of CRT responders from non-responders as well as individual responsiveness of patients [2]. Additionally, quantification of left ventricular dyssynchrony acutely after myocardial infarction can predict LV remodeling [3].

Echocardiographic methods to assess regional myocardial motion suffer under several limitations such as a poor acoustic window or through-plane motion. Magnetic resonance (MR) CSPAMM tagging [4,5] combined with harmonic phase analysis (HARP, 6) allow for fast and accurate quantification of regional motion parameters. However, the acquisition of multi-slice MR tagging data covering the whole heart in short- and long axis orientations is associated with extensively long acquisition times and prone to slice misregistration. In this study, a novel accelerated 3D tagging acquisition scheme [7,8] was employed allowing the acquisition of volumetric 3D tagging data of the entire LV in only three breath-holds. Accordingly, the method is easily integrated into a clinical protocol including volumetric, perfusion and viability measurements. Similar spatial and temporal resolutions are obtained as in conventional 2D tagging acquisitions.

The 3D tagging technique was applied to quantify LV dyssynchrony in patients after acute myocardial infarctions as a model causing dyssynchrony relative to healthy controls. Features of three-dimensional motion patterns were correlated with the presence of scar tissue as measured with late enhancement images.

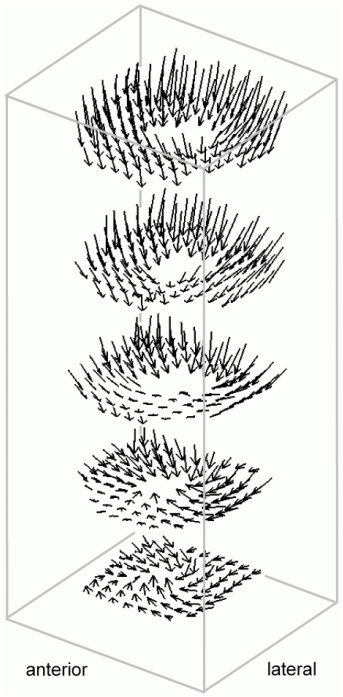

Figure 1: *3D displacement field of a representative healthy volunteer. Displacement of the base towards the apex, radial contraction and apical rotation can be observed*

Methods: 3D CSPAMM-tagged images of the entire LV were acquired in 16 patients (14 male / 2 female, age = 60.7±11.5 years) with myocardial infarction and in 17 controls (9 male / 8 female, age = 36.0±13.9 years). Patients were measured 10.5 days (minimum 2 days, maximum 39 days) after myocardial infarction and showed an ejection fraction of 40.7±9.5%. A hybrid multi-shot, segmented echo-planar imaging sequence was applied to acquire motion encoded data in all three orthogonal directions (Philips 1.5T, Best, NL) [7,8]. Spatial resolution in each encoding direction was 3.0x7.7x7.7mm³ with a temporal resolution of 30ms. Data acquisition was split into three navigator controlled breath-holds of 18 heartbeats duration each. For viability assessment late enhancement images were acquired in all patients (Gadobutrolum, 0.25 mmol/kg bw).

Midwall circumferential shortening (*csh*, %) and time to maximum *csh* (T_{max}) were extracted from 6 sectors on 8-11 cardiac levels (48-66 segments/heart) using a home-written peak-combination HARP [6,9] software. The standard deviation of T_{max} of all segments was calculated as a measure of temporal LV dyssynchrony. Spatial LV dyssynchrony was assessed by calculating the standard deviation of *csh* at end-systole over all segments.

Results: Figure 1 shows the 3D displacement field at end-systole in a healthy volunteer. In patients, T_{max} of 351.7±34.7ms was not different from the controls with 351.4±39.2ms. However, the standard deviation of T_{max}, which served as a measure of temporal LV dyssynchrony, was significantly higher in patients (77.9±14.4ms vs. 43.9±9.1ms, p<0.0001) and linearly dependent on LV enhanced area (Fig.2, p<0.01). Mean LV *csh* at end-systole was significantly reduced in patients (12.0±3.3%) compared to healthy volunteers (18.1±1.9%, p<0.0001). Similarly, the standard deviation of LV *csh* at end-systole (spatial dyssynchrony) was different between patients (7.0±1.1%) and controls (4.3±0.7%, p<0.0001). Results for a representative patient with anterior myocardial infarction are shown in Fig.3.

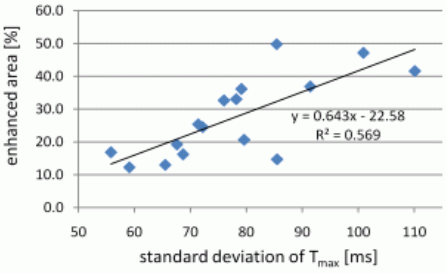

Figure 2: *Linear regression between LV dyssynchrony and amount of scar tissue for patients after myocardial infarction (p<0.01).*

Conclusion: Accelerated 3D MR tagging acquisition provides detailed information on temporal and spatial dyssynchrony of the entire left ventricle. In combination with viability information obtained from late enhancement images, this approach shows potential to quantify both dyssynchrony and scar fast and accurately and thus may prove an important measure for CRT planning and prediction of LV remodeling.

References: [1] Kass DA, J Cardiovasc Electrophysiol 16: 35-41, 2005. [2] Helm RH, et al., Circulation 115(8): 953-61, 2007. [3] Mollema SA, et al., JACC 50(16): 1532-40, 2007. [4] Axel L, et al., Radiology 171(3): 841-845, 1989. [5] Fischer SE, et al., MRM 30: 191-200, 1993. [6] Osman N, et al., MRM 42: 1048-60, 1999. [7] Rutz AK, et al., Proc. ISMRM: 759, 2007. [8] Rutz AK, et al., MRM, in press. [9] Ryf S, et al., JMRI 20: 874-8, 2004.

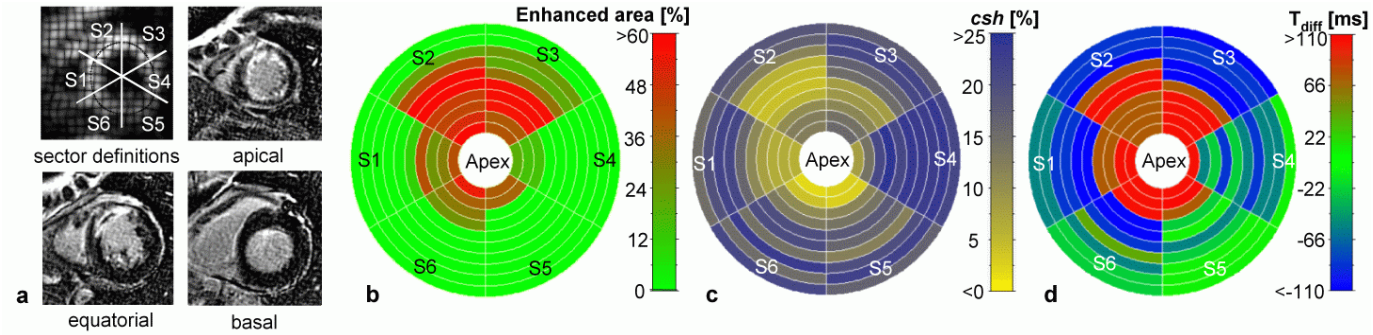

Figure 3: *Results for a representative patient with anterior myocardial infarction. a) Tagged image (slice through 3D data set) with sector definitions and exemplary late enhancement images on 3 cardiac levels. b) Bull's eye plot of viability: Regions exhibiting late enhancement due to scar tissue. c) Bull's eye plot of deformation: Circumf. shortening (csh) at end-systole. d) Bull's eye plot of dyssynchrony: Time difference T_{diff} map for maximum csh relative to the mean T_{max}. Blue = early, red = delayed, green = regular timing of contraction.*