Accelerated Whole-Heart 3D CSPAMM for Myocardial Motion Quantification

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Introduction: Myocardial tagging using CSPAMM [1] is a powerful method to assess local motion characteristics of healthy and diseased myocardium. To capture the complex three-dimensional motion pattern during contraction and relaxation of the heart, multiple 2D tagged slices are usually acquired in long-axis and short-axis orientation. These approaches are however associated with long acquisition times and might be prone to slice misregistration. While two-dimensional techniques are widely used, there is only little experience with three-dimensional tagging techniques [2,3]. Long acquisition times have prevented the application of 3D tagging in patients so far. In this work, a fast method for acquiring tagged 3D data sets is proposed and first results from patients with myocardial infarction are presented.

Methods: Three-dimensional tagging was implemented using three sequentially acquired 3D data sets with line tag preparation in each of the three spatial dimensions. Compared to previous work applying lattice tag preparation [2,3], sequential line tag preparation has following potential advantages: i) one-dimensional tag preparation in each of the three 3D data sets allows for reduced k-space sampling orthogonal to the tag pattern direction and thus for faster data acquisition [4], ii) reduced signal T2* decay during tag line preparation given the shorter tagging preparation time relative to lattice tag preparation, iii) acquisition of only 3x2 instead of 8 harmonic peaks (with 2 redundant peaks), iv) improved suppression of B0 induced artifacts in each line tag 3D data set by peak-combination HARP [5].

In order to further reduce scan time, a reduced field-of-view method using localized tagging preparation was implemented [4].

Four healthy volunteers and two patients with myocardial infarction were scanned with a 3D TFEPI-sequence on a 1.5T scanner (Philips Medical Systems, Best, NL): tag distance=7mm, FOV=108x108x108mm^3, EPI-factor=7, TFE-factor=4. The voxel size for each of the three datasets was 3.00x7.71x7.71mm^3 with the highest resolution aligned with the tagging direction in each of the three data sets. Depending on the heart rate, 19 to 25 time frames were recorded with a temporal resolution of about 30ms. In order to prevent tag fading during the cardiac cycle, an optimized ramped flip angle approach was applied (final flip angle=20º, [6]). Three navigator controlled breath-holds (gate=4mm) of 18 RR-intervals duration each were performed to acquire the data.

For data evaluation peak-combination HARP [5] was adapted to 3D. Eight to ten midwall contours consisting of multiple landmark points were defined on different short axis slices regularly distributed over the left ventricle (Fig.2a). A heart phase with good blood-myocardium contrast was chosen for contour definition. The contours were subsequently HARP-tracked [7] in 3D space over all time frames.

In patients, delayed enhancement images were acquired in addition to correlate scar areas with motion characteristics detected with tag data.

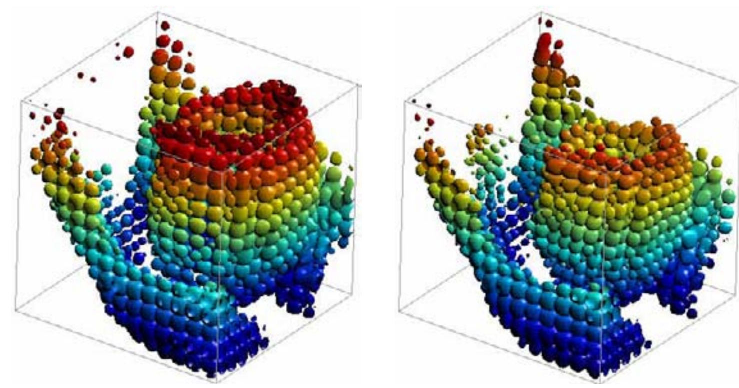

Figure 1: 3D isosurface representations of tagging data composed from three line tag 3D data sets showing the left ventricle of a healthy volunteer in relaxed and contracted state (720ms & 387ms after the R-wave). Color encoding corresponds to cardiac level.

Results: In all measured subjects contours could be tracked throughout the cardiac cycle. A 3D isosurface representation of the data sets composed from the three tag line prepared 3D data sets acquired in a healthy volunteer 720ms and 387ms after the R-wave is shown in Fig.1. In patients reduced circumferential shortening was detected in the infarcted sectors along with a prolonged rapid filling phase of the entire left ventricle. The hypokinetic regions corresponded well with regions exhibiting hyperenhancement (Fig.2,3).

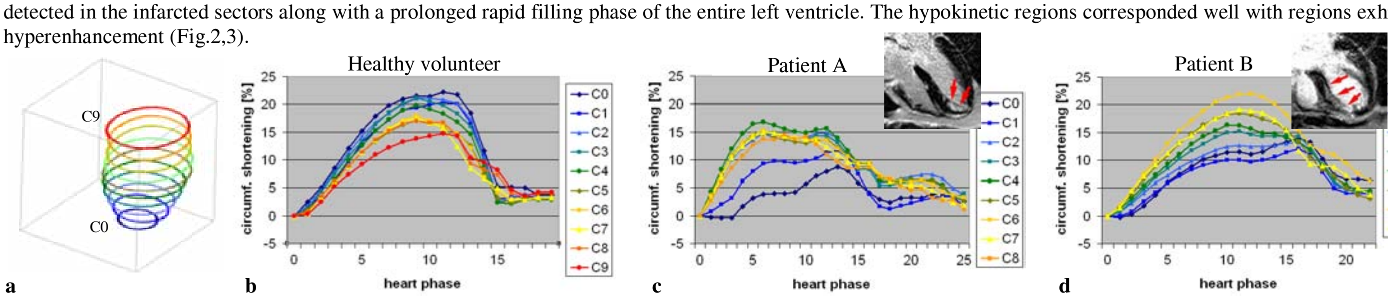

*Figure 2: **a**) Short-axis contours covering the apical (C0) up to the basal (C9) cardiac levels in a healthy volunteer. **b,c,d)** Circumferential shortening of each contour in one healthy control and in two patients. Delayed enhanced images are shown with the patient data (10min after contrast injection, arrows mark infarcted region).*

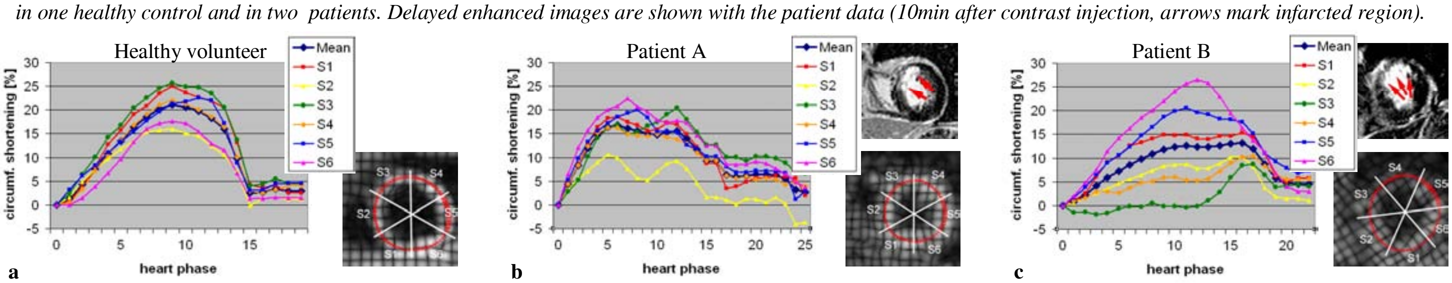

***Figure 3** Circumferential shortening for six different secors on the level of the infarction (equatorial level for healthy control). Sector definition and delayed enhanced images (patients) are shown in the same orientation (10min after contrast injection, arrows mark infarcted region).*

Conclusion: An accelerated 3D tagging acquisition method has been proposed enabling assessment of 3D motion information with whole heart coverage in three short breath-holds. Compared to previous 3D methods requiring extended breath-holds and cooperation the present approach is well accepted by patients.

References: [1] Fischer SE, et al., 1993, MRM 30: 191-200. [2] Ryf S, et al., 2002, JMRI 16: 320-325. [3] Ryf S, et al., Proc ISMRM 2004, #657. [4] Fischer SE, et al.,1994, MRM 31:401-13. [5] Ryf S, et al., 2004, JMRI 20: 874-8. [6] Ryf S, et al., 2005, JCMR 7: 693-703. [7] Osman NF, et al., 1999, MRM 42(6): 1048-60.