High Resolution Myocardial Tagging

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Introduction: Myocardial tagging is a technique for the quantitative assessment of regional and global function [1]. Currently, tagged acquisitions may be limited in either spatial or temporal resolution by breath-hold duration, impeding the use of tagging as a tool for the study of the higher order motion of the heart. Furthermore, temporal blurring limits the technique's ability to discriminate between the small timing differences in regional activation or relaxation. We present a state-of-the-art technique for the acquisition of images with both high temporal resolution (~10ms per frame) and high spatial resolution (0.9x2.0mm voxels). The results are presented in terms of circumferential shortening (Ecc), an index for myocardial function.

Methods: Two normal volunteers were imaged (as approved by our IRB) on a 1.5 T LX CV/i scanner (GE, Waukesha, WI) utilizing a custom built 8-channel receiver [2] and an 8-coil chest phased array (Nova Medical, Wakefield, MA). Perpendicular striped tagging cines were acquired as described in [3]. Imaging was performed using a hardware optimized SSFP sequence [4]. TSENSE [5] was applied with acceleration rate of 3, leading to temporal resolutions ~10ms (3*TR). Other imaging parameters were: 384x180 matrix size, ~36cm FOV, ~0.94x2.0mm spatial resolution, ±125kHz bandwidth, TR = 3.3-3.4, TE = TR/2, 40° flip angle, 8 mm slice thickness, 21 heartbeat acquisition and offline reconstruction. Semi-automated tag tracking was performed using the FastTag program which utilizes the UNTETHER algorithm [6]. As a simple measure of motion, three short axis slices (1 basal, 1 mid, 1 apical, 2 tag directions) and 6 long axis slices were analyzed. Circumferential strain (Ecc) was calculated for 8 circumferential segments for each of the short-axis slices.

Results: The combination of TSENSE and the short of TRs of the optimized SSFP pulse sequence produced images with sufficient SNR for clinical assessment and quantitative analysis. Figure 1 displays typical beginning and end-systolic images from the striped tagged acquisitions. Figure 2A displays the Ecc, in units of percent shortening, for 4 different regions of a mid-ventricular slice. Figure 2B displays Ecc for two septal wall segments at mid-ventricular and basal levels of the heart. The differences in the onset of relaxation are visible, indicating that the increased temporal resolution may be used to observe the regional distribution of events.

Discussion: The combination of a parallel imaging technique with a high efficiency SSFP sequence allowed for the acquisition of high temporal and spatial resolution scans within a single standard breath-hold. The benefits from higher temporal resolution are demonstrated by the detection in differences in the onset of relaxation at different regions of the heart. Furthermore, the use of SSFP led to easier semi-automated analysis due to excellent blood-myocardium contrast and tunable tag persistence [3]. Most of the major features of the curves in Figure 2 are visible in standard lower resolution images. However, the timing sequence of events such as isovolumic relaxation, rapid filling and the regional distribution of onset times cannot be measured with standard tagging acquisitions due to temporal and/or spatial blurring. Furthermore, the use of the high SNR SSFP imaging technique with a parallel imaging technique allows for acquisitions of excellent temporal resolution without the need for EPI-based techniques [7], leading to better tag-myocardium contrast and excellent and blood-myocardium contrast.

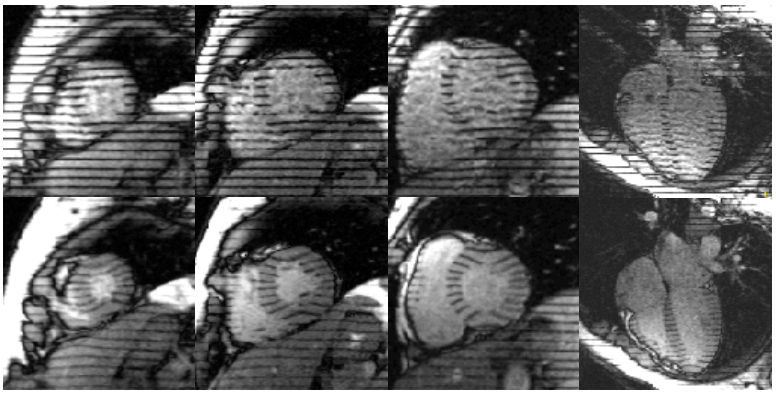

Figure 1: Three representative end-diastolic (top) and end-sytolic (bottom) short-axis (L-to-R: Apical, mid-ventricular, basal) and a long axis tagged images. A matrix size of 384x180 was used to achieve 0.93x2.0mm in-plane spatial resolution. The use of the TSENSE accelerated imaging technique led to a temporal resolution of 10ms. Each slice was acquired over a 21 heartbeat breath-hold.

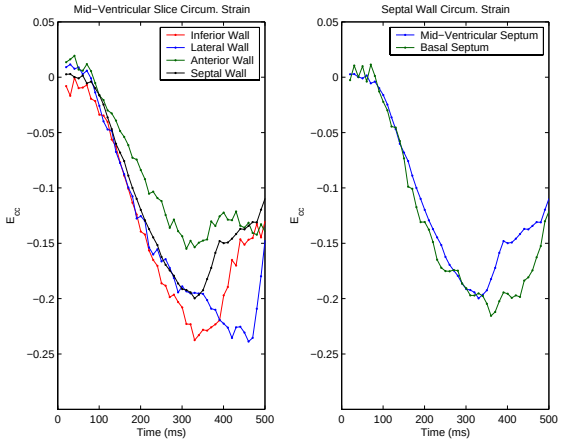

Figure 2: High resolution strain curves from various regions of a mid-ventricular slice (A) and from two segments of septal wall (B). Note the differences in the onset times of relaxation (~350ms).

References:

[1] Zerhouni EA, Radiology 169(1):59-63 (1988).
[2] Morris HD, et al. *10th ISMRM*, pp 61 (2002).
[3] Herzka DA et al. *MRM* 49:329–340 (2003)
[4] Derbyshire JA, et al. *10th ISMRM*, pp 2359 (2002)
[5] Kellman P, et al. *MRM* 45(5):846-52 (2001)
[6] Denney Jr TS, et al. *MRM* 49(4): 734-754 (2003)
[7] Epstein FH et al. *8th ISMRM*, pp1609 (2000)