Combination of T2-Magnetization Preparation and Slice Interleaved Inversion Recovery for Improved Motion Correction of Myocardial Extra-cellular Volume Mapping using Spoiled Gradient Echo Imaging

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Target Audience

Scientists and clinicians who are interested in myocardial tissue characterization.

Purpose/Introduction

The extracellular volume fraction (ECV) can be calculated using co-registered native and post-contrast T_1 maps and shows promise for the detection of diffuse myocardial fibrosis. ECV mapping are usually performed using SSFP-based T_1 mapping sequences[1]. However the SSFP signal is associated with increased susceptibility to the B_0 field inhomogeneity, is T_2 dependent, and sensitive to magnetization transfer, which can result in regional T_1 variations and substantial bias in T_1 estimates[2,3]. To overcome these limitations, slice interleaved inversion recovery[4] spoiled gradient echo (GRE) imaging has been recently proposed for T_1 mapping. However, the co-registration of native and post-contrast GRE T_1 scans is challenging since GRE images with short inversion time (TI) have very different intensity/contrast between pre and post-contrast imaging and GRE images with long TI have very low contrast between blood and myocardium limiting the ability to estimate complex motion. In this study, we sought to develop and evaluate combining T_2-magnetization preparation imaging and slice interleaved inversion recovery spoiled gradient echo imaging to facilitate the co-registration process and improve ECV mapping.

Materials and Methods

Proposed sequence: The proposed T_1 mapping sequence enables simultaneous acquisition of 5 slices under free breathing conditions. The acquisition scheme is illustrated in Figure 1. Each slice is first acquired using a T_2 magnetization preparation (T_2Prep) pulse (Figure 1a). Several inversion recovery (IR) experiments are then performed using the same TI (TI_1) (Figure 1b). In each IR experiment, 5 slices are acquired over 5 heartbeats following the IR pulse using interleaved ordering. Each IR experiment used a different slice ordering. The block in Figure 1b is finally repeated using a different TI. Respiratory motion was compensated using prospective respiratory navigators combined with retrospective image registration[6].

T_1/ECV map reconstruction: All T_1 maps were reconstructed using a 2-point model fit and an affine motion correction approach. Co-registration of native and post-contrast T_1 scans was performed by image registration of the T_2Prep image of both scans using a non rigid approach combining an affine and local non rigid motion estimation step[7].

In-vivo experiment: All data were acquired on a 1.5 T Phillips scanner. Two healthy subjects (36±25y, 1 male) and 5 patients (57±14y, 4 males) referred for clinical CMR evaluation were recruited and scanned with the proposed sequence. Native and post-contrast imaging (at ~15 and ~30 minutes after injection of 0.1 mmol/kg of gadobenate dimeglumine) were performed. All scans used an ECG triggered acquisition (TR/TE/α=4.3/2.1ms/10°, FOV=280×272 mm^2, voxel size=2×2 mm^2, slice thickness=8 mm, number of phase-encoding lines=43, linear ordering, 10 linear ramp-up pulses, SENSE factor=2.5, half Fourier=0.75, bandwidth=382Hz/pixel).

Data Analysis: All analyses were performed for the three mid-ventricular slices of uncorrected and motion corrected ECV maps (using identically motion corrected T_1 maps). Dice similarity coefficient (DSC: 0=no overlap, 1=ideal registration) and myocardial boundary error (MBE) were measured. Subjective quality analysis of native T_1 maps, post-contrast T_1 maps and ECV map was performed using a 4-point scale (1-Poor/non diagnostic 2-Fair; 3-Good; 4-Excellent) by an experienced reader who was blinded for the reconstruction scheme[1]. Student paired t-test and Wilcoxon sign rank tests were used for statistical analysis of continuous and categorical data, respectively.

Results

The proposed approach led to improved DSC (0.87±0.03, vs. 0.65±0.25, p<0.001), reduced MBE (1.2±0.5 mm, vs. 3.2±2.9 mm, p<0.001), and improved ECV map quality scores (3.2±1.0, vs. 2.8±1.2, p=0.014). The subset of ECV maps (Filtered ECV maps) which were created with good or excellent native and post-contrast T_1 maps (with a score ≥ 3) received a quality score of 3.6±0.6 (vs. 3.1±1.1, p=0.022, uncorrected).

Conclusions

Combined T_2-magnetization preparation and slice interleaved inversion recovery with spoiled gradient echo imaging improves the co-registration of native and post contrast T_1 scans and the overall ECV map quality.

Acknowledgements

Grant support from NIH R01EB008743-01A2 and Samsung Electronics.

References

[1] Kellman, JCMR, 2012
[2] Kellman, JCMR, 2014
[3] Roujol, Radiology, 2014
[4] Weingärtner, MRM, 2014
[5] Brittain, MRM, 1996
[6] Roujol, MRM, 2014

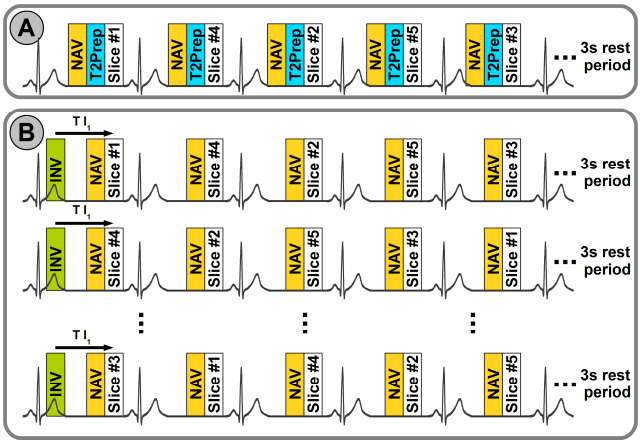

Figure 1. Scheme of the proposed sequence.

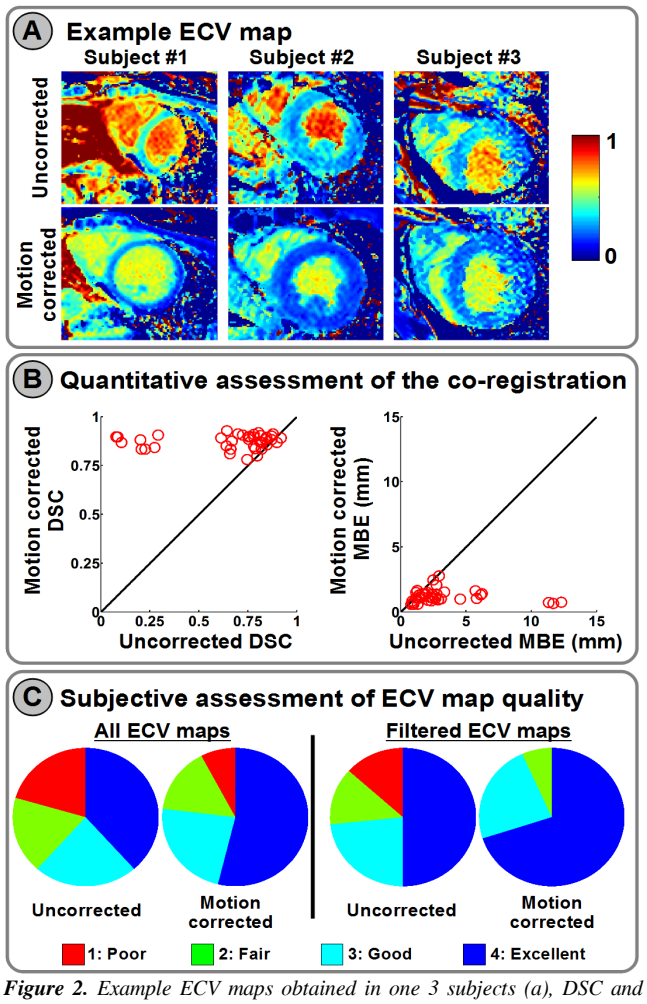

Figure 2. Example ECV maps obtained in one 3 subjects (a), DSC and MBE (b), and subjective assessment of overall ECV map quality (c). The proposed sequence yields excellent co-registration of native and post-contrast T_1 scans and substantially improve the quality of ECV maps.