Whole-Heart Water/Fat resolved Spiral Imaging for Coronary MRA and Fatty Myocardial Infiltrations

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Introduction

MRI is a very valuable tool in diagnosing different forms of cardiac diseases. In particular, coronary MR Angiography (CMRA) has been shown to allow accessing the status of the coronary tree or the patency of corresponding bypass grafts [1]. Whole heart approaches, benefitting from parallel reception, have been introduced to image the entire coronary tree in a single acquisition [2, 3]. To improve the visibility of the coronaries in their epicardial bed, fat suppression is employed in CMRA. However, the suppressed fat signal also contains helpful diagnostic information for a number of cardiac diseases [4,5]. In myocardial infarction or in the presences of suspicious cardiac masses, the intra-myocardial fat represents an important diagnostic indicator. Burke et al. [6] has reported that fibro-fatty infiltration of the myocardium is associated with sudden death. Thus, the fat signal and its distribution could have high prognostic value. Therefore, in this work whole heart CMRA-type imaging is proposed that delivers both, the coronary tree information and simultaneously the fat signal distribution at the same spatial resolution. To sample the data efficiently, spiral imaging [7] is used embedded in a chemical shift encoding approach. This allows to separate chemical shifts from ΔB_o, additionally facilitating off-resonance corrected non-Cartesian water/fat resolved imaging [8]. In this work this concept was applied to show that efficient, fat-suppressed, off-resonance corrected spiral imaging can be performed in CMRA and intra-myocardial fat detection application with large volume coverage.

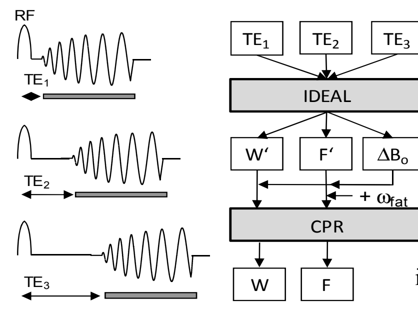

Fig.1. Spiral three-point Dixon water /fat separation and off-resonance correction. (left) Encoding scheme for the spiral, (right) DIXON-CPR post-processing (separation / correction).

Methods

Spiral gradient echo imaging was performed using chemical shift encoding employing a fixed k-space trajectory, which was shifted in time to sample three individual echoes (see Fig.1a). An iterative Dixon reconstruction [9] was applied to the reconstructed spiral images to separate water and fat signal contributions followed by a Conjugate Phase Reconstruction (CPR) [10] using the estimated field map to deblur the water and the fat image (see Fig.1). Healthy volunteers were scanned on a 1.5T system (Achieva, Philips Healthcare) with a 32-element cardiac coil, using magnetization prepared 3D interleaved stack-of-spirals gradient echo imaging (matrix:192², FOV:256×256mm², 50 slices, thickness: 3mm, AQ-window: 15ms, 12 interleaves, TR/TE_1: 23ms/1.6ms). For preparing the longitudinal magnetization, T2-preparation (TE: 50ms) and outer-volume suppression was applied. The magnetization thus prepared was read out using a gradient echo train consisting of five spiral interleaves using a flip-angle sweep ensuring that the last shot tips down all longitudinal magnetization still available. For chemical shift encoding a time increment of ΔTE: 1.5ms was employed while keeping TR fixed. Real-time navigator gating with prospective motion correction, using a rigid body motion model, and EKG gating was applied acquiring the data in mid/late diastole resulting in a total scan time around 8 minutes for a 50% gating efficiency.

Parallel imaging was used to partly compensate for the longer scan time of three-point Dixon imaging. SENSE was applied in the stack direction (R: 2). Besides accelerating the acquisition, SENSE as an phase-conserving unfolding operation also leads to a significant reduction in computational complexity, because it merges all 32-channel data into a single image. DIXON-CPR reconstruction is performed subsequently as a post-processing step using three 3D data sets (see Fig.1).

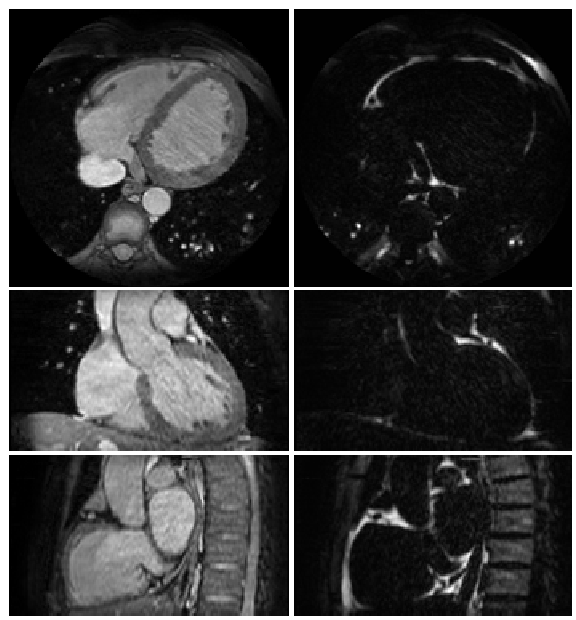

Fig.2. 3D magnetization prepared water/fat-resolved spiral (AQ-window: 15ms) data with different reformats (transverse / coronal / saggital) shown. Water-only data (left): coronary angiogram fat-only data (right): intra-myocardial fat detector.

Results and Discussion

All volunteer scans were successful and yielded good image quality (see example Fig.2). This confirms the basic feasibility of this dual-information approach, merging CMRA with intra-myocardial fat detection. Such an approach can help to improve the diagnostic value and also the scan efficiency. The Dixon approach used in this study is in particular very advantageous for the spiral sampling scheme. The ΔB_o map delivered by the water/fat separation approach is very useful to improve spiral image quality during CPR-post-processing. However, this concept could also be applied to Cartesian sequences, which show much higher flexibility to parallel imaging acceleration, which is restricted for simplicity reasons to one dimension in the stack-of-spirals approach. Another issue concerns the used T_2 preparation sequence. This also acts on the fat signal reducing its amplitude and thus reducing the fat SNR. One potential solution is to use an MTC-based magnetization preparation instead, which maintains the desired blood-myocardium contrast, but does not have any impact on fat. Outer volume suppression has been shown to be important because the Dixon separation is not able to cope with signal folded-in form areas exposed to different main fields. The Dixon approach proposed in this work provides a sensitive means of detecting intra-myocardial fat with positive signal contrast while facilitating conventional inspection of the coronaries. Further technical improvements like the use of 2-point Dixon approaches and studies in real patients have to be carried out.

References

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