Water/Fat resolved Whole-Heart Imaging for Coronary MRA

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Introduction

Whole heart coronary MR-angiography methods (CMRA) utilizing parallel reception allow to image the entire 3D coronary tree in clinical acceptable scan times [1]. For an improved visualization of the vessel structures, CMRA is typically combined with fat suppression. Recent studies showed, however, that the fat in and around the heart could be of diagnostic value [2,3]. For instance, the amount of fat deposition in the myocardium can be used to characterize chronic myocardial infarction. Moreover, in cases of suspected cardiac masses, the separation of water and fat components improves the diagnostic confidence. In the last years, Dixon techniques have replaced conventional fat suppression methods, because of their lower sensitivity to B_0 inhomogenities.

In this feasibility study, we propose a gradient multi-echo sequence for whole heart CMRA which acquires two or three echoes at both polarities of an alternating readout gradient, allowing an iterative water/fat separation. This approach promises high contrast CMRA providing additional fat images without extra scan time. CMRA is often performed with a T_2 magnetization preparation (T_2Prep) to increase the contrast between the blood and the myocardium [4]. But this pre-pulse also acts on the fat signal, reducing its amplitude and thus the SNR of the fat image, which might be undesirable, especially when small amounts of intra-myocardial fat are of interest. Therefore, we additionally investigated the use of a magnetization transfer contrast (MTC) pre-pulse [5] instead, which maintains the desired contrast between blood and myocardium, but has no influence on the fat signal [6].

Methods

Data were acquired in six healthy volunteers on a 1.5T clinical scanner (Achieva, Philips Healthcare, Best, Netherlands) using a 32-element cardiac coil. Four different scans were performed for each volunteer: **1.)** Conventional whole heart CMRA with Spectral Presaturation Inversion Recovery (SPIR) fat suppression and T_2Prep. **2.)** Two-point-Dixon scan with T_2Prep. **3.)** Two-point-Dixon scan with MTC. **4.)** Three-point-Dixon scan with T_2Prep. The differing scan parameters are shown in Table 1. The protocols use a higher pixel bandwidth as the SPIR protocol for two reasons. First, the water/fat shift should be small (0.3 pixel) to achieve a good alignment of the water and fat images. Second, for the two-point-Dixon, the acquisition window should be as long as for the SPIR protocol to maintain the same image quality in terms of cardiac motion. The following scan parameters were identical for all four protocols: flip angle 30°, in-plane FOV 256 × 256 mm^2, voxel size 1.0 × 1.0 mm^2. 100 transversal slices with thickness of 1.5 mm (interpolated from 3.0 mm) were acquired per 3D dataset. SENSE was used in two directions: R=2 in the stack direction (feet-head) and R=2 in the phase encoding direction. The latter was chosen from right to left, to prevent ghosting artifacts from the chest wall, introduced by residual breathing motion. Therefore, outer volume suppression was applied to the arms. Navigator gating with prospective motion correction was applied (5 mm acceptance window). All protocols apply the same number of shots (156) and therefore the total scan time is identical: Approximately 5min, assuming a gating efficiency of 50% and a heart-rate of 60 bpm. ECG gating was applied with data acquired during mid-diastole. During reconstruction of the Dixon data, the inconsistencies between the odd and the even echoes were corrected using reference data [7]. Subsequent, SENSE unfolding is performed resulting in one stack of 100 slices for each of the two or three echo times. With this already reduced amount of data, an image-based iterative water/fat separation was performed, using an algorithm similar to [8] for the three-echo-data, whereas for the two-echo-data a method proposed in [9] was used. The SNR for fat was determined in the chest wall, the SNR for water in the arterial blood, estimating the corresponding noise in the lungs for reference.

	SPIR T_2Prep	2P Dixon T_2Prep	2P Dixon MTC	3P Dixon T_2Prep
AQ window	108 ms	108 ms	108 ms	152 ms
TE1 / ΔTE	1.5s / -	1.8s / 1.7s	1.8s / 1.7s	1.8s / 1.7s
Pixel bandwidth	217 Hz	723 Hz	723 Hz	723 Hz
SNR fat image	-	50 ± 17	60 ± 16	64 ± 25
SNR water image	30 ± 12	30 ± 7	28 ± 6	40 ± 9

Table 1: Scan parameter and resulting SNR (mean and standard deviation) for the four investigated protocols.

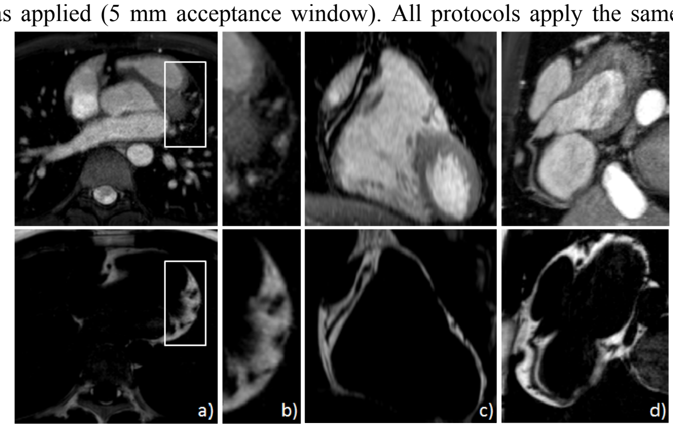

Figure 1: 3D whole heart CMRA. Water (top) and fat (bottom) data of a selected volunteer (2 point Dixon acquisition with T_2Prep). **a)** axial reformat **b)** local magnification of a) **c)** coronal reformat **d)** multi-planar right coronary artery (RCA) reformat. Note the water/fat vessel correspondence.

Results and Discussion

All volunteer scans were successfully performed and yielded good and consistent image quality. Figure 1 shows the final water and fat reconstruction of one selected volunteer. Resulting SNR values over all volunteers are given in Table 1. As expected, the SNR in the fat images is approx. 20% higher for the MTC- than for the corresponding T_2Prep-protocol. The three point Dixon protocol delivers a higher SNR in both, the water and the fat image, compared to the 2 point Dixon protocol, according to the longer acquisition window. The SNR in the water images is almost equal for the SPIR protocol and the two point Dixon protocol, both using the T_2prep pre-pulse. The major coronary vessels can be depicted clearly with the Dixon protocols. No ΔB_0- and/or ΔB_1-problems are visible as sometimes reported for SPIR. Due to the almost binary and very strong contrast in the fat images, the location of small epi-cardial vessel structures is sometimes easier to find in the fat image than in the water image (Figure 1b). This can augment vessel characterization and can provide new and helpful diagnostic information. Furthermore, the fat images can be used for the quantification of the epi-cardial fat burden in 3D, which can represent potentially additional diagnostic information of interest and could be helpful to detect intra-myocardial fat deposition. In conclusion, two-point-Dixon protocols, can completely replace the SPIR based protocols for CMRA with no scan time penalty.

References:

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