3T Coronary MRA using 3D Multi-interleaved Multi-echo Acquisition and VARPRO Fat-water Separation

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Introduction: Coronary MR Angiography is a valuable tool for non-invasive assessment of coronary arteries. Presently, contrast-enhanced, fat-saturated, ECG-triggered and navigator-gated 3D spoiled gradient-echo sequence is employed for whole-heart Coronary MRA at 3T[1]. However, large static field variations at 3T frequently result in non-uniform fat-suppression over the field-of-view (FOV), obscuring the delineation of coronary arteries. Multi-echo Dixon approaches utilizing iterative decomposition have been shown to provide robust fat-water separation even in the presence of large field inhomogeneities. In this study, an ECG-triggered navigator-gated 3D spoiled gradient-echo multi-interleaved multi-echo (GRE-MEMI) pulse sequence is introduced which utilizes VARPRO[2] fat-water separation to achieve reliable fat-suppression and provides enhanced visualization of coronary arteries.

Methods: A 3D GRE-MEMI sequence (Fig.1) was implemented on a 3T whole-body MR scanner (MAGNETOM Trio, Siemens AG) with support for navigator-gating and ECG-triggering. VARPRO algorithm iteratively obtained fat-water decomposition using multiple echoes. The multi-interleaved scheme enabled shorter echo time increments, which reduced ambiguity in decomposition and improved fat-water separation.

Parameter name	Fat-saturated GRE	GRE-MEMI
No. of Echoes	1	4
TE	1.54 ms	1/2/3/4 = 1.35/2.47/3.6/4.7 2 ms
TR	3.4 ms	5.42 ms
Flip Angle	18°	18°
Resolution	1.3mm x 1.3mm x 1.5mm	1.3mm x 1.3mm x 1.5mm
No. of Slices	32	32
Parallel acquisition / acceleration / reference lines	GRAPPA / 2 / 24	GRAPPA / 2 /24

Table 1: Typical imaging parameters for conventional 3D fat-saturated GRE and 3D GRE-MEMI measurements.

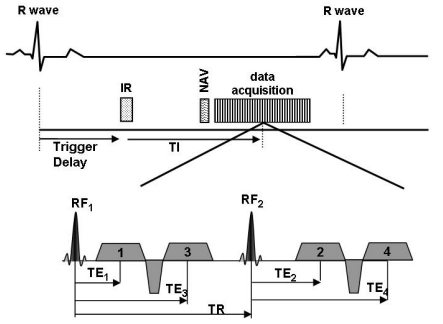

Figure 1: Pulse Sequence Diagram for 3D ECG-triggered, navigator gated, spoiled gradient echo sequence with multi-echo multi-interleave readout (GRE-MEMI). Multiple echoes are used during reconstruction by VARPRO for iterative water-fat decomposition. No fat-saturation prepulse is applied separately. Multi-interleaved scheme achieves shorter echo time increments between multiple echoes, which improves the fat-water separation.

Six healthy volunteers were imaged pre- and during contrast agent administration targeting right coronary artery (RCA) or left coronary artery (LCA). Typical imaging parameters for pre-contrast GRE-MEMI scan are listed in Table1. Additionally, a conventional single-echo fat-saturated GRE scan was acquired for comparison. Thereafter, 0.2 mmol/kg Gd-DTPA (Magnevist®, Bayer Healthcare) was slowly injected at a rate of 0.3ml/s followed by 20ml of saline solution injected at the same rate. GRE-MEMI acquisition with inversion preparation (TI=300ms) was started 30s after the injection of the contrast agent.

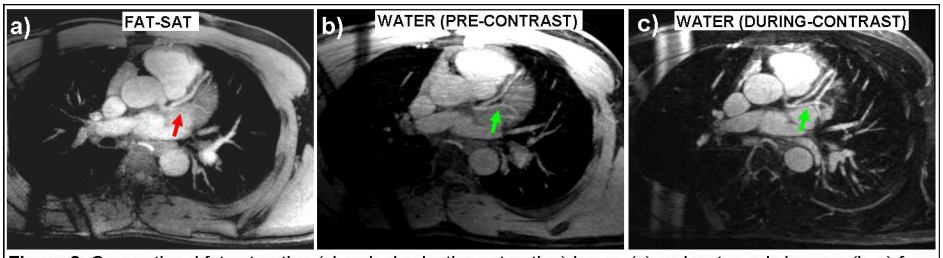

Figure 2: Conventional fat saturation (chemical selective saturation) image (a) and water-only images (b, c) from a targeted left coronary artery (LCA) measurement at 3T in a healthy volunteer. Conventional fat saturation yields suboptimal results in some areas (a - red arrow), however, robust fat suppression is achieved over the entire FOV using the proposed technique without (b) and with (c) the use of contrast agent. The delineation of left circumflex (LCX) coronary artery is clearly improved in water-only images obtained using VARPRO fat-water decomposition (b, c - green arrow).

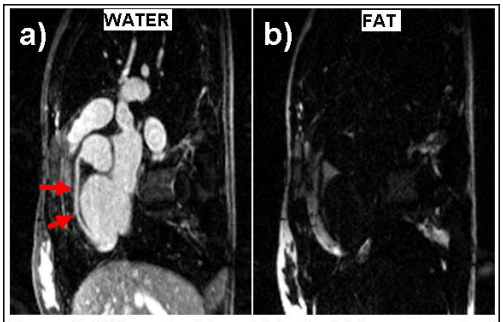

Figure 3: Water-only (a) and fat-only (b) images acquired from a healthy subject during slow infusion of contrast media. Note that water and fat signals are effectively separated and the RCA (a - red arrows) is sharply delineated. Compared to pre-contrast GRE measurements, use of contrast agent increases contrast-to-noise ratio between blood and background tissues.

Results: Targeted coronary MRA images were successfully acquired in all volunteers with effective fat-water separation. The average total imaging time was 9.85±1.4min with navigator efficiency of 34.1±5.1%. Fig.2 shows LCA images from a healthy volunteer. Conventional fat-saturation yields suboptimal fat-suppression whereas robust fat-suppression is evident in water-only images which provide clear depiction of coronary artery. Fig. 2(c) and Fig. 3 illustrate enhanced contrast-to-noise with the use of contrast agent in the delineation of left anterior descending and left circumflex coronary arteries, and right coronary artery, respectively.

Conclusions: 3D GRE-MEMI sequence was successfully utilized for targeted fat-water separated coronary artery imaging in healthy volunteers. VARPRO fat-water separation provides reliable fat-suppression at 3T and improves the delineation of coronary arteries. Moreover, without the use of a fat-saturation prepulse, readout duration within a heartbeat can be extended to cover the entire quiescent period without any degradation in fat-suppression. Multi-echo acquisition results in increased acquisition time, however, the resulting water-only image provides the benefit of increased SNR due to intrinsic averaging effect of fat-water separation. Further improvement in acquisition speed using higher parallel imaging factors is desired to achieve 3D whole-heart coverage with reasonable imaging time.

References:

[1] Bi X. *et al*, MRM 58, 2007.
[2] Hernando D. *et al*, MRM 59, 2008.