Navigator-Gated Whole Heart Coronary MRI with 3D isotropic Double Echo TrueFISP UTE

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Introduction

Coronary MRA provides a non-invasive approach for the detection of coronary artery disease. Previous works have shown that whole heart 3D radial techniques simplify the scanning procedure with no compromise in image quality [1-4]. Ultra-short Echo Time (UTE) MRI allows for the detection of short T2 components (T2 of the order of 100 μs) in tissue before they have decayed [5, 6]. This is potentially interesting for a range of cardiovascular MR applications such as atherosclerotic plaque imaging, where UTE imaging has been shown to depict calcified regions [7-9].

Until now the UTE method has been based on a Fast Low Angle Shot (FLASH) contrast [10] where, an excitation pulse α tips the magnetization M_0 so that the transverse component $M_t=M_0\sin\alpha$ can be measured and, after the readout gradient, is spoiled through gradient and RF spoiling, so that only the longitudinal component $M_l=M_0\cos\alpha$ is available for the next excitation. Balanced Steady State Free Precession (b-SSFP, also known as TrueFISP, FIESTA, and balanced FFE) [11, 12] is an SSFP technique in which the magnetization M_t is preserved by applying fully compensated gradients that null the zeroth moment between RF-pulses. TrueFISP provides a different contrast, higher SNR and lower sensitivity to eddy currents than FLASH.

A navigator-gated isotropic 3D radial double echo UTE TrueFISP sequence could provide state-of-the-art TrueFISP whole heart coronary images plus UTE images at almost no extra cost, other than a slightly longer TR.

In this work a navigator-gated isotropic 3D radial double echo UTE TrueFISP sequence was used to acquire whole heart coronary images.

Materials and Methods

The 3D radial multi-echo UTE sequence and reconstruction algorithm were implemented on a 1.5 T clinical scanner (MAGNETOM Avanto, Siemens AG HCS, Erlangen, Germany). It consists of a 60μs long non-selective RF pulse followed by a 40μs transmit/receive switch time and a 100% asymmetric data acquisition from the centre to the surface of a sphere. In order to achieve the shortest possible TE, data acquisition starts during ramp-up time of the readout gradient. The online reconstruction program consists of a Kaiser-Bessel Gridding algorithm (window width = 3 and $\beta = 4.2054$) with sampling density compensation modified to correct for undersampling. The following sequence parameters were used for volunteer examinations of the heart: TR = 3.7 ms, double echo TE=0.07 and 2.4 ms, $\alpha = 15°$, BW = 1302 Hz/pixel, 40000 projections, Tacq= 13 min. Fat saturation and T2 preparation pulses were included to improve image contrast.

Results

Preliminary results of 3D TrueFISP UTE images of the heart with an isotropic resolution of $(1.3\ mm)^3$ were acquired on a clinical scanner with a total scan time of about 13 min. Figure 1 shows reformatted views of TrueFISP UTE (a, d) and symmetric echo (b, e) 3D isotropic volume data sets of the heart of a healthy volunteer and their corresponding subtractions (c, f). Due to insufficient fat saturation, opposed phase effects can be observed in the TE=2.4ms images (b,e), which result in bright signal in the subtraction images.

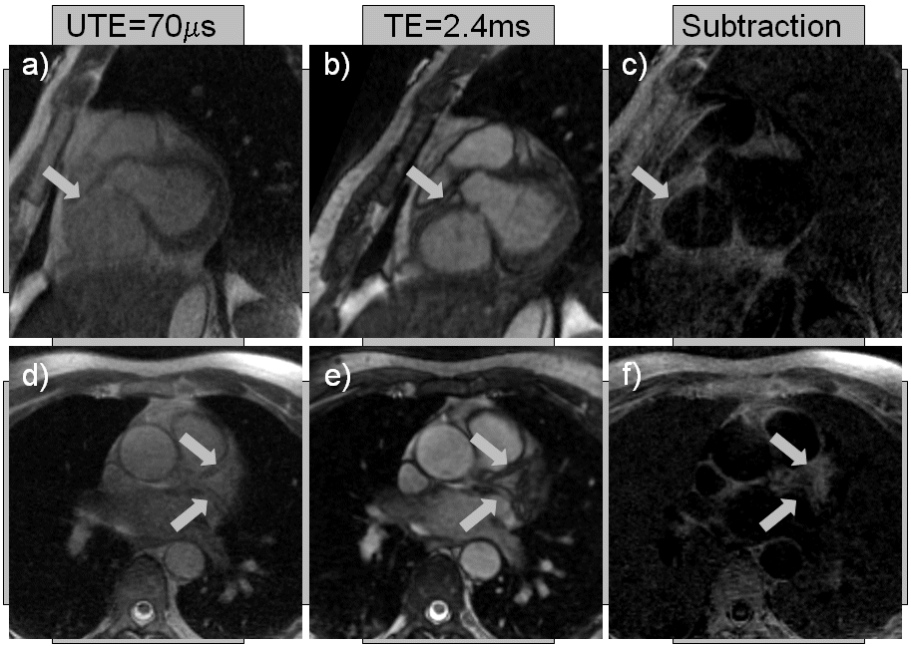

Figure 1

Reformatted views of TrueFISP UTE (a, d) and symmetric echo (b, e) 3D volume data sets of the heart of a healthy volunteer and their corresponding subtractions (c, f).
Measurement parameters: TR = 3.7ms, TE=0.07 and 2.4ms, $\alpha = 15°$, BW = 1302Hz/pixel, 40000 projections, Tacq= 13 min.
Isotropic resolution: $(1.3\ mm)^3$.

Fat saturation and T2 preparation pulses were included to improve image contrast. However, opposed phase effects can be observed in the TE=2.4ms images (b,e) due to incomplete fat saturation. These appear as bright signal areas in the difference image. No other bright signal areas are observed in the difference image, as expected in a healthy volunteer.

Discussion

The feasibility of free-breathing, navigator-gated isotropic 3D Radial Multi-Echo TrueFISP UTE Imaging has been demonstrated.

In order to avoid the opposed phase effect on the symmetric echo images, TE could be increased to 4.7ms. However, this would increase TR and, therefore, the overall measurement time and the risk to get TrueFISP dark-band artifacts. Therefore, future work will focus on improved fat saturation in order to keep TE and TR as short as possible.

A navigator-gated isotropic 3D radial double echo UTE TrueFISP sequence could provide state-of-the-art whole heart coronary images plus UTE and difference images at almost no extra cost, only slightly longer TR, opening up the possibility to obtain a new contrast for a range of cardiovascular MR applications, such as detection of calcification in atherosclerotic plaque, depiction of fibrosis in the heart or visualization of iron labeled cells. Future work will focus on atherosclerotic plaque patient studies in order to evaluate the clinical value of this technique.

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