Three Echo Dixon Water-Fat Separation for Cardiac Black Blood Turbo Spin Echo Imaging

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Introduction

Turbo spin echo (TSE) sequences with black blood preparation pulses are an important component of cardiac MRI. It is commonly used for tissue characterization and anatomical assessment of the myocardium, e.g. for edema imaging aiming at the differentiation of acute from chronic myocardial infarction. TSE benefits from high SNR and the availability of good T1 or T2 weighting. So far it is often combined with an additional fat suppression prepulse to improve contrast. But recent studies showed, that the fat in and around the heart could be of diagnostic value [1,2]. For example, the amount of fat deposition in the myocardium can be used to characterize chronic myocardial infarction. In cases of suspected cardiac masses, the separation of water and fat components is essential for a confident diagnosis. Recently, the combination of multi-echo Dixon imaging with a fly-back gradient echo sequence was proposed for water/fat separated imaging of the heart [1,2]. Either a three-echo-train with in- and out-phase echoes [1] or a four-echo-train [2] was used. In this feasibility study, we propose the combination of black blood TSE with a three echo GRASE-like readout and an iterative water/fat separation reconstruction. Acquiring data at both polarities of the readout gradient increases the sampling efficiency. Appropriate signal correction in combination with accelerated parallel imaging allows fast water/fat resolved cardiac imaging. The pulse sequence is similar to the one proposed in [3], but without restrictions to the inter echo time.

Methods

Data were acquired in healthy volunteers on a 1.5T clinical scanner (Achieva, Philips Healthcare, Best, The Netherlands) using a 5-element cardiac coil. A modified multi-slice black blood TSE sequence was used as shown in Figure 1. Data were acquired ECG-triggered at a delay of 650 ms after the RR-wave. The black blood preparation consisted of a non-selective 180° pulse followed by a slice-selective 180° pulse. After the blood T1-specific and heart rate depended delay time, TSE data collection was started. In the TSE, phase encoding was applied only once after each 180° refocusing pulse, such that the alternating readout gradient encoded the same *k*-space line three times. Beside the central Spinecho, a gradient echo was acquired at $\Delta TE = \pm 1.8$ ms, respectively. 16 different *k*-space lines were encoded per cardiac cycle in a linear order, preceded by 4 startup echoes, resulting in an effective echo time of TE = 130ms. A short axis view was depicted with an in-plane FOV of 350×318 mm^2 and a voxel size of 1.15×1.15 mm^2. 10 slices were acquired with a slice thickness of 10 mm, each in one breath-hold of approx. 16 s. A SENSE factor of 2 was used; therefore, coil sensitivity maps were acquired in a preceding reference scan. During reconstruction, first, the inconsistencies between the odd and the even echoes were corrected using reference data measured just before the scan [4]. SENSE unfolding is performed resulting in one stack of ten slices for each of the three echo times. With this already reduced amount of data, an image-based iterative water/fat separation was performed using a region-growing algorithm for local B_0 inhomogeneity estimation, similar to the method described by Yu et al. [5].

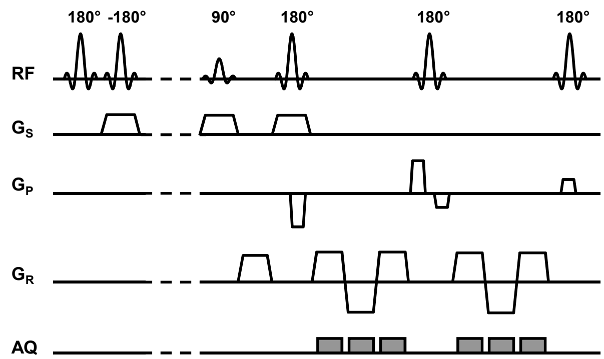

Figure 1: Schematic black blood Turbo Spin Echo pulse sequence with water/fat chemical shift encoding using a three-echo bipolar gradient readout.

Results and Discussion

Figure 2 shows the final water and fat reconstruction of two selected slices of a selected volunteer in a short axis view. Very good image quality, blood signal suppression inside the ventricle and water/fat separation was achieved. The iterative least-squares decomposition method is very flexible concerning the echo spacing. It has been shown that proper specification of the ΔTE is advantageous in terms of SNR [6], but in principle any choice of ΔTE is possible. Therefore, in any existing TSE cardiac protocol, the so far applied fat suppression could be exchanged easily with the presented method of acquiring three echoes instead. Beside the more stable fat suppression in the presence of B_0 inhomogeneity, the additional information of the distribution of water and fat could be of great diagnostic benefit. In addition, the prolonged overall signal sampling time results in an improved SNR in the water image. This is especially true, when compared to an improper fat suppression, which does not only remove signal from the fat species, but in some image regions also from water tissue. Of course, the main disadvantage of all multi-echo Dixon water/fat separation imaging methods remains, i.e. the scan time is prolonged compared to a one echo imaging method with spectral selective excitation or spectral selective suppression. Here, the time between two refocusing pulses has to be increased to be able to sample three echoes instead of one. To use the same effective echo time and to prevent image blurring caused by a prolonged echo train, the number of *k*-space lines encoded during one cardiac cycle has to be reduced compared to the one echo scan. This will increase the number of needed cardiac cycles, and hence the overall scan time. But so far, this three-echo bipolar GRASE-like readout is the most efficient way to acquire data at three different echo times for TSE water/fat separated cardiac imaging.

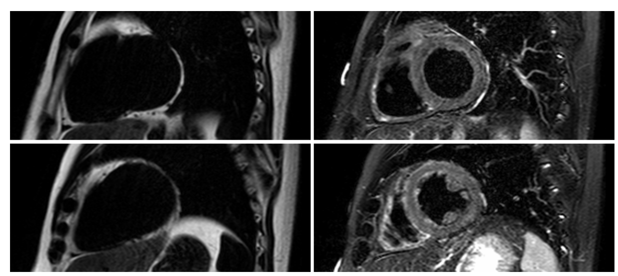

Figure 2: Black blood water/fat resolved Turbo Spin Echo applied in a volunteer. Selected slices shown (left: fat data, right: water data).

Conclusion

The proposed modification of an established black blood TSE sequence is capable of adding very useful diagnostic information at the cost of a slightly prolonged overall scan time. Even when only the water image is of interest, the method can be superior to a one echo method with prepulse fat suppression in terms of increased SNR and better fat suppression in the presence of B_0 inhomogeneity. Further studies are needed to show the applicability in the clinical practice.

References

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