Water Fat Separation with TSE BLADE Based on Three Points Dixon Technique

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Introduction

Chemical shift based methods are often used to achieve uniform water fat separation that is insensitive to magnetic field inhomogeneities. Many spin echo (SE) [1], gradient echo (GRE) and turbo spin echo (TSE) [2] approaches sample data in a Cartesian trajectory. For the three points Dixon technique, three echoes are acquired with identical time intervals between them. Due to the chemical shift between water and fat, time dependent phase shifts are induced between those echoes, which are called in-phase and out-of-phase echoes. This work demonstrates that Cartesian sampling is sensitive to motions such as pulsation and flow which cause artifacts that degrade the image quality. To address this problem, we propose a non Cartesian sampling method, TSE BLADE, together with a new reconstruction algorithm. This technique acquires one in-phase and two out-of-phase images with two TSE BLADE sequences, respectively; the in-phase image is reconstructed with the method given in [3], while the two out-of-phase images are reconstructed by using all blades from the in-phase image for phase correction. This approach enjoys the known benefits of the BLADE sequence, which is less sensitive to motion, and has higher SNR (compared to Cartesian sampling).

Methods

Sequence: A normal TSE BLADE sequence (Fig. 1A) is used to acquire the in-phase image, a double echo TSE BLADE sequence (Fig. 1B) with equal time shift τ from spin echo time is designed to acquire the two out-of-phase images. This design ensures that gradient delays and eddy current imperfections will have the same impact on all acquired images, so that all blades for the in-phase image can be used to do the phase correction for the two out-of-phase images. The reconstruction consists of a 2D re-gridding operation for the in-phase and out-of-phase images, followed by a water fat separation calculation based on phase unwrapping. The process of phase correction for the out-of-phase echoes is shown in Fig. 2. Blades from the in-phase image are transformed to the image domain after filtering by a pyramid filter. The phase of each blade from the in-phase image is subtracted from the corresponding blade from the out-of-phase image after transformation into the image domain. Then the phase corrected image is transformed back to k-space and the following reconstruction steps are identical to the in-phase image.

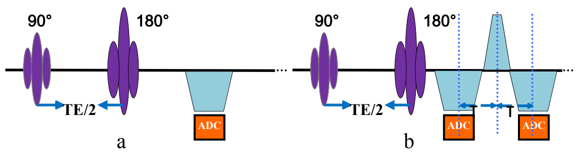

Fig. 1: In-phase and out-of phase sequence diagram.

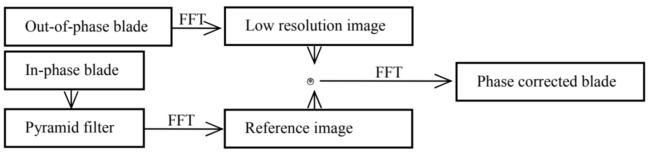

Fig. 2: Phase correction flow chart for an out-of-phase blade.

Human Study at 1.5T: Volunteer head and knee images in a transverse plane were scanned on a Siemens MAGNETOM ESSENZA 1.5T scanner. The TSE BLADE Dixon acquisition parameters were: (head) FOV=300mm×300mm, matrix=256×256, TE=214ms, TR=6000ms, slice thickness=5mm, turbo factor=35; (knee) FOV=165mm×165mm, matrix=256×256, TE=116ms, TR=5000ms, slice thickness=4mm, turbo factor=15. The parameters for the comparison TSE sequence were: (head) FOV=300mm×300mm, matrix size=256×256, TE=213ms, TR=6000ms, slice thickness=5mm, turbo factor=35; (knee) FOV=165mm×165mm, matrix size=256×256, TE=116ms, TR=5000ms, slice thickness=4mm, turbo factor=12, spectral fat suppression (FatSat).

Evaluation: The water and fat head images from the new TSE BLADE Dixon sequence are compared to results obtained from a standard TSE Dixon sequence. For the knee, the water image from the TSE BLADE Dixon sequence is compared to an image from a standard TSE sequence using spectral fat suppression.

Results

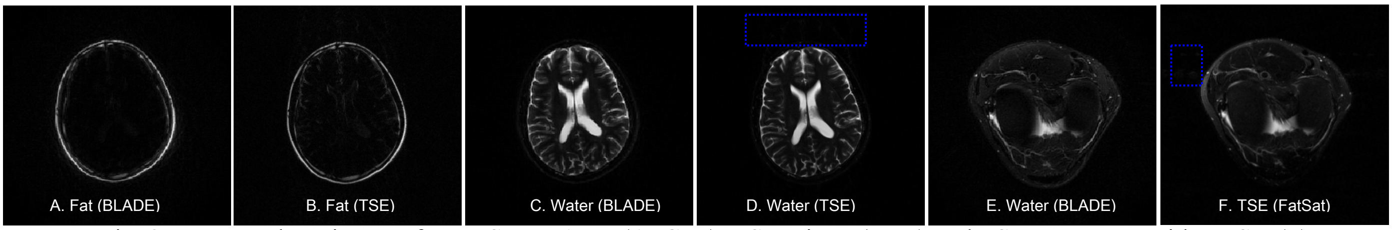

Fig. 3: Water and Fat images from TSE BLADE (A, C, E), TSE Dixon (B, D) and TSE sequences with FatSat (F).

Fig. 3 shows comparisons between images acquired with BLADE Dixon, TSE Dixon and TSE with FatSat. The water and fat images of the head obtained by the BLADE Dixon and TSE Dixon method are shown in Fig. 3A and C, Fig. 3B and D respectively. The water and fat images are correctly separated with the BLADE Dixon method. Furthermore, the residual CSF signal and artifacts from flow in Fig. 3A are much lower than in Fig. 3B. In Fig. 3C no motion artifacts are visible in the area where artifacts are visible in the TSE Dixon image (shown by the blue rectangle in Fig. 3D). Figs. 3E and 3F display water images from the BLADE Dixon and a standard TSE sequence with FatSat respectively. In Fig. 3F obvious pulsation artifacts are visible, while there are no artifacts in the BLADE Dixon image (Fig. 3E).

Discussion & Conclusion

A Dixon method based on TSE BLADE has shown to separate water and fat images correctly. It inherits the known benefits of the BLADE sequence, it is less vulnerable to artifacts caused by rigid body motion, pulsation, flow etc. and it has higher SNR due to multiple sampling of the k-space center. It is important to note that the phase correction applied on the out-of-phase images reconstruction insures that the phase information from the fat-water chemical shift is kept, while eliminating artifacts caused by echo shifting.

References

[1] G. H. Glover *et al.* MRM, 18:371-383 (1991). [2] Scott B *et al.* MRM, 54:636–644 (2005). [3] James G. Pipe, *et al.* MRM, 42:963–969 (1999).