IDEAL with Turbo-PROP

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Introduction

Turbo-PROP [1] was developed to provide wider blades for diffusion-weighted and T1-weighted imaging. Zhou et al. [2] used Turbo-PROP to acquire multi-echo images to assess the T2* effects and improve the SNR of diffusion-weighted imaging. Here we propose a different approach to acquire multi-echo images from Turbo-PROP sequences. These images can be synthesized to get a final high-quality image, and at the same time can be used to separate the water and fat signals based on the phase difference with the IDEAL algorithm [3].

Methods

The Turbo-PROP pulse sequence is diagrammed in Figure 1a. It consists of M RF refocusing pulses to generate a spin echo train. For each spin echo period, N (N = 5 in our experiment, N = 3 in Figure 1) gradient echoes are formed by a bipolar readout gradient. For each TR (blade), the k-space lines from the same echoes are grouped together to form sub-blades (indicated by different colors in the diagram). The location of the sub-blades is shuffled with different blade angles (Figure 1b). Different sub-blades are reconstructed separately, forming M images. These images can be combined using a RMS method to generate a high-quality image, or using the IDEAL algorithm to separate the water and fat signals, as shown here.

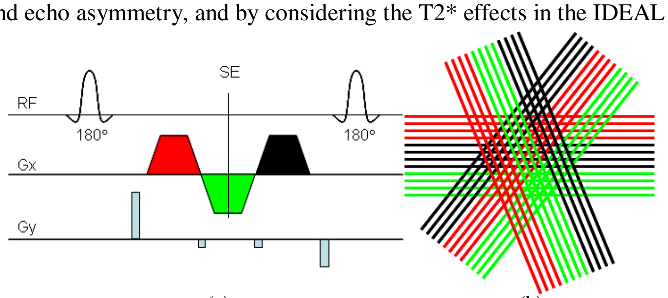
In our experiments, five gradient echoes are evenly distributed in each SE period. In this case, optimal SNR for the water and fat images will be acquired if the all the echoes are shifted by pi/2 (asymmetric), as seen in Figure 2a. However, theoretic calculation [4] for the regular acquisition parameters on 3T (FOV = 24, Resolution = 256, BW = 250Hz) show that, the SNR penalty is very subtle if we distribute the five echoes symmetrically (Figure 2b). This symmetric distribution improves the quality of the spin-echo image and the sampling efficiency, which are very important for the generation of T1 weighted images.

Experiments and Results

T1 weighted images of healthy volunteers were acquired with an 8-channel Brain coil and a 12-channel spine coil on a GE SIGNA 3T scanner. Key data acquisition parameters were: TR = 800ms, NEX = 9, ETL = 5, Turbo = 5, FOV = 24cm, matrix size = 256 for the brain series, and TR = 800ms, NEX = 9, ETL = 5, Turbo = 5, FOV = 28cm, matrix size = 384 for the spine series. Water images (Figure 3a, c) and fat images (Figure 3b, d) for brain (Figure 3a, b) and cervical spine (Figure 3c,d) are shown here.

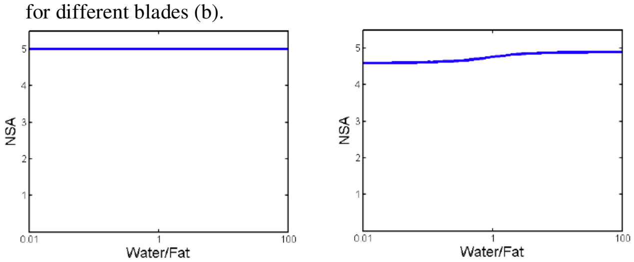
Discussion

Compared with the regular FSE IDEAL approaches, our method can significantly reduce the scan time (similar to [5]), and provide the possibility of motion correction (by PROPELLER). Images can be T1 or T2 weighted. The results can be further improved by carefully adjusting the echo-spacing and echo asymmetry, and by considering the T2* effects in the IDEAL algorithm as did in [6, 7].



(a) (b)

Figure 1. The pulse sequence diagram (a) and k-space data acquisitions for different blades (b).



(a) (b)

Figure 2. The NSA (Number of Signal Average) changes with the Water/Fat ratio in 3T and 0.8 pi off-resonance conditions for Asymmetric (a) and Symmetric (b) distribution of five gradient echoes.

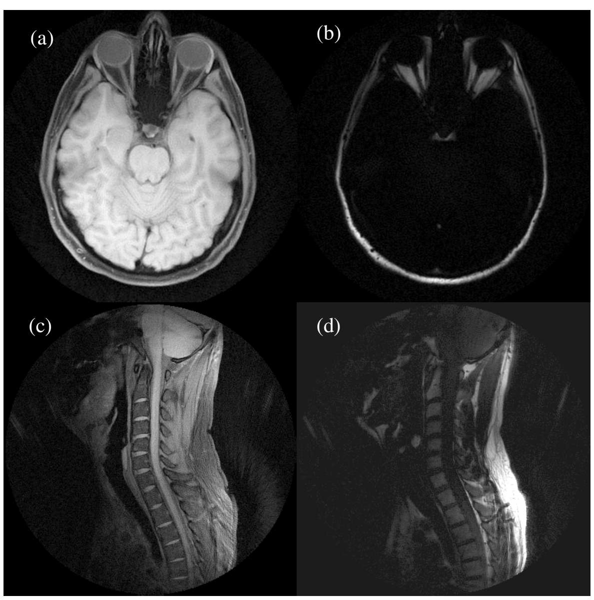


Figure 3. Water and fat separation of the brain and cervical spines. Images were T1 weighted.

References

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Acknowledgements

We thank Dr. Altbach from the University of Arizona for providing the IDEAL and Cramer-Rao simulation code. This work was supported in part by GE Healthcare.