Comparison of bSSFP and GRE at 9.4 Tesla

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Introduction

Balanced steady-state free precession (bSSFP) pulse sequences have found widespread use at clinical field strengths because of short acquisition times, unique contrast and increased signal to noise characteristics compared to similarly acquired gradient-recalled echo (GRE) methods[1,2]. To date there has been no published demonstration of the advantages of bSSFP over GRE at an ultrahigh magnetic field strength that quantifies the advantages *in vivo*. This study performs the simple task of comparing fully optimized bSSFP images versus acquisition matched GRE images in mouse brain at 9.4 T.

Methods

All images were acquired on a 31 cm actively shielded 9.4 T magnet (Magnex, Yarnton, UK) with a Direct Drive console (Varian, Palo Alto, CA) using a 120 mm gradient coil with a peak amplitude of 400 mT/m and slew rate of 2000 mT/m/ms. A 30 mm millipede birdcage was used to obtain brain images of a mouse breathing a 1.5% isoflourane in O_2 ventilation mixture. The shim was optimized over the prescribed imaging region using RASTAMAP[3] while an automated 'tweak' of the bSSFP gradient pulses was performed using the method described by Bowen *et al.* [4] in order to minimize readout banding artifact. The 2D GRE and bSSFP acquisitions were both parameter and time matched for direct comparison using TE=1.85 ms, TR=3.70 ms, flip angles varied between 10 and 90 degrees and a full bandwidth of 83 kHz. Each image was acquired from a fully relaxed state (10 sec delay) and subsequently driven to steady state using 1350 pre-pulses (700 ms SLR pulse with a time bandwidth product of 6). The images were acquired at 128 x 128, 1.6 cm FOV with a 1 mm slice thickness and 10 averages. Each resultant image was acquired in 4.7 seconds. Phase cycling was not used to alleviate banding in bSSFP images.

Results

Figure 1 shows the results of the acquisition matched data demonstrating the obvious SNR improvement of bSSFP over GRE. Figure 2 is a plot of the calculated signal-to-noise ratio versus echo time for both the bSSFP and GRE image acquisitions. The average SNR advantage over the flip angle range was 3.4 (std=0.2). At a flip angle of 30 degrees the contrast difference between gray and white matter in the mouse brain was measured to be 43% and 6% for bSSFP and GRE, respectively. Figure 3 shows a typical bSSFP image acquired using CISS phase cycling with two frequencies.

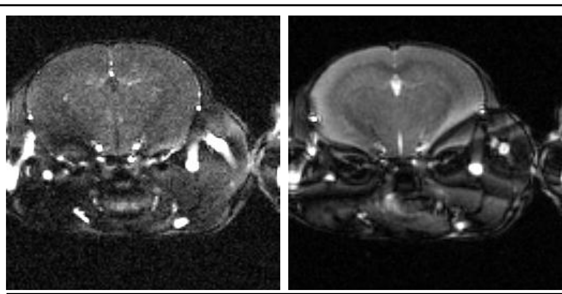

Figure 1. Acquisition parameter and time matched images using GRE (left) and bSSFP (right) demonstrating the obvious SNR advantage.

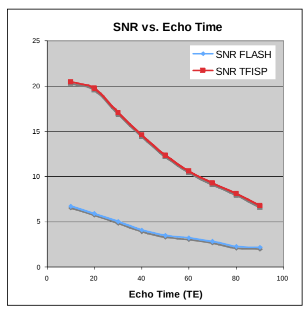

Figure 2. Signal-to-noise ratio calculated in matched bSSFP (red) and GRE (blue) acquisitions versus echo time.

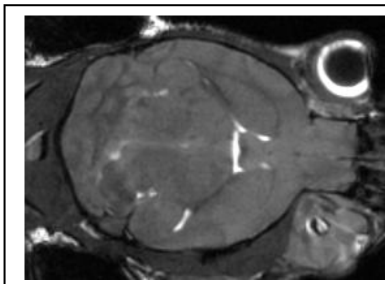

Figure 3. Balanced SSFP image acquired using a 2 frequency CISS phase cycling scheme.

Discussion

To date little work has been done at ultrahigh magnetic field strengths to demonstrate the advantages of using balanced acquisition methods to enhance signal to noise and contrast characteristics in images. This study demonstrates a clear increase in the signal to noise per unit time of 3.4 using the bSSFP sequence over a matched GRE acquisition. To achieve the same SNR in the GRE acquisition one would need to image almost 12 times longer. In addition, using a flip angle of 30 degrees we observe contrast between gray and white matter of mouse brain of 43% in bSSFP images versus 6% in the GRE images.

References

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