Susceptibility and T2/T1 Weighted Contrast Enhancements in Rat Brain using bSSFP at 9.4T

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Introduction

Balanced steady-state free precession (bSSFP) pulse sequences have found widespread use at clinical field strengths, particularly for cardiac applications, because of short acquisition times, high contrast and increased signal to noise characteristics compared to similarly acquired gradient echo (GRE) methods[1]. We have previously demonstrated there to be a greater than 3 times signal to noise advantage, per unit time, using a fully optimized bSSFP sequence over a similarly matched gradient echo acquisitions[2]. The current study demonstrates unique image contrast at high magnetic field strength observed in both high resolution *ex vivo* and *in vivo* rat brain images.

Methods

All images were acquired on a 31 cm actively shielded 9.4 T magnet with a Direct Drive console (Varian, Palo Alto, CA) using 120 mm gradient coil operating at SR 3000 mT/m/ms. A 30 mm Varian millipede birdcage RF coil was used to acquire the *ex vivo* rat brain images while a 2.5 cm quadrature Tx/Rx surface coil was used for the *in vivo* experiment. For the *ex vivo* rat brain a 3D bSSFP acquisition with a 'long' echo (TE=6.06 ms, TR=12.12 ms, flip angle=35 degrees, BW=39 kHz) was used to collect the high resolution (75 μm isotropic) volume (2.88 cm x 1.44 cm x 1.28 cm FOV; 4 frequencies; 4 averages; 1 hour 47 min acq). An *in vivo* rat brain was similarly acquired (TE=5.46 ms, TR=10.92 ms, flip angle=35 degrees, BW=28 kHz) following an acute stroke of the middle ICA within a 2.88 cm x 1.44 cm x 1.28 cm FOV; 4 frequencies; 1 average; 6 min acq and a resultant image resolution of 100 μm x 100 μm x 600 μm.

Results

Figure 1 (left) shows a representative horizontal section of an *ex vivo* rat brain (formalin fixed) acquired using the 3D bSSFP sequence described. The brain volume was acquired at 75.0 μm isotropic resolution and subsequently reconstructed using sum-of-squares. Contrast between gray and white matter was calculated to be 0.26 using $([S_{GM}-S_{WM}]/[S_{GM}+S_{WM}])$. Figure 1 (right) shows a slice from an *in vivo* rat brain during a stroke model. The primary area of stroke is highlighted within the circled region but of particular note is the hemispherical sensitivity to blood deoxygenation outside the stroke region.

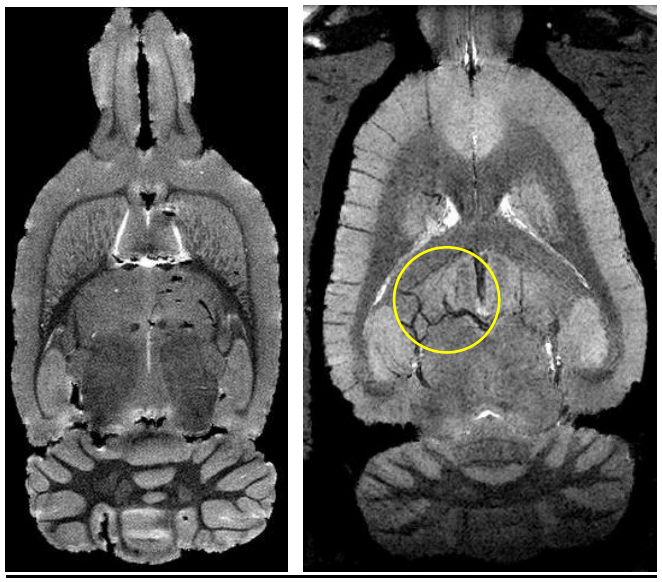

Figure 1. (Left) Single slice from a 3D bSSFP acquisition of formalin fixed *ex vivo* rat brain and (right) from an *in vivo* rat brain during a stroke model. The primary stroke area is shown within the circle.

Discussion

The use of bSSFP pulse sequences for brain imaging at ultra high magnetic field strength has not been extensively explored to date. We have shown previously a clear advantage in using this sequence over acquisition time and parameter matched GRE techniques. Balanced SSFP in the steady state exhibits unique T_2/T_1 image weighting[3] in areas rich with iron content like the cerebellum and deep gray matter such as the thalamus. This weighting, coupled with its sensitivity to local off resonance signal at high magnetic field strength, particularly at 'long' echo time, produce homogeneous images with unique brain tissue contrast rivaling SWI approaches but with higher SNR and less sensitivity to the directionality of structures in the phase images. This is useful when visualizing the venous vasculature in normal and diseased states. Furthermore, images with this exquisite contrast can be acquired in a time that is an order of magnitude faster than equivalent gradient echo techniques.

References

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