High Resolution MR imaging of trabecular bone using steady state free precession (SSFP) at 1.5T and 3T

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Introduction:

High resolution MRI is a useful noninvasive technique for assessing trabecular bone micro-architecture in the context of osteoporosis. Previous publications on this subject use 3D-fast gradient echo (3D-FGRE) [3] and spin-echo [4] techniques. The goal of this paper is to optimize 3D Fast Imaging Employing Steady State Acquisition (FIESTA), a fully refocused steady state free precession (SSFP) technique, for high resolution trabecular imaging. We evaluated the signal to noise ratio (SNR) efficiency of the sequence by comparison with the 3D-FGRE technique based on gradient-recalled acquisition in the steady state (GRASS). We imaged eight normal volunteers in the proximal femur, calcaneus and distal tibia at 1.5T and 3.0T.

Methods:

We developed a computer simulation of the steady state response under a fully refocused SSFP sequence following the linear system analysis in [2]. The steady state magnetization response depends both on imaging parameters, namely TR, TE, readout bandwidth (BW) and flip angle (α), and on tissue parameters, namely T1 and T2 [1]. Using BW and α as the control parameters we optimized the system with a focus on SNR and SNR efficiency. In high resolution MRI trabecular bone appears as dark regions in contrast with the bright fat and water signals from the marrow making SNR synonymous with Contrast-to-Noise Ratio (CNR). For the simulation model we used T1 = 280 ms, T2=160ms at 1.5T and T1= 370 ms, T2=110ms at 3.0T [5].For FGRE acquisitions, we used the existing optimized GRASS protocol [3].

Figure 1A **Figure 1B**

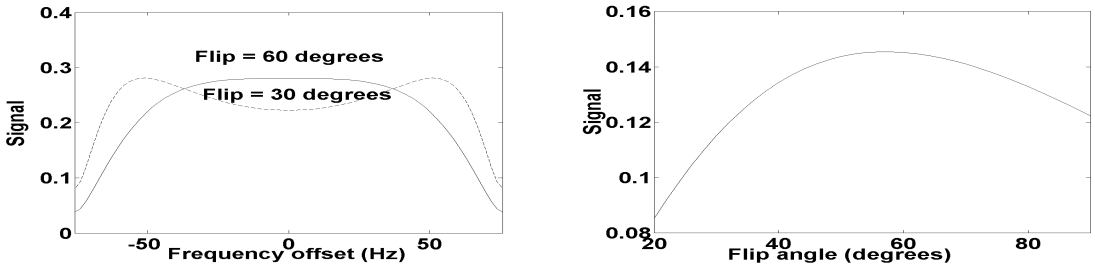


Fig 1A is a simulation plot of steady state signal magnitude against resonant frequency offsets for different α. Fig 1B is a simulation plot of steady state signal magnitude against α for BW=16 KHz and T1,T2 corresponding to 3T

We imaged eight normal volunteers on a 1.5T GE Signa Scanner using a U.S.A Instruments four coil phased array receiver coil and on 3T (GE Signa) Scanner using a similar coil from Nova Medical. The image acquisition matrix was 512x384 in all scans. The calcaneus and tibia images, acquired in the sagittal and axial planes respectively, have an in-plane resolution of 190 um and a slice thickness of 500 um Coronal images of hip were acquired with an in-plane resolution of 234 μm and slice thickness of 1500 μm.Acquisition parameters for the hip are shown in Table 1.

Table 1

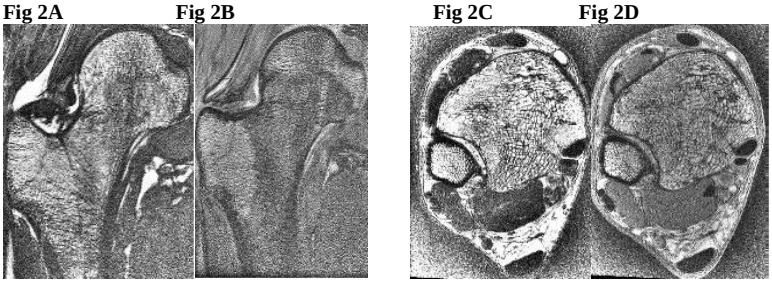
Parameters	1.5 T		3T	
	FIESTA	FGRE	FIESTA	FGRE
TR/TE/ α	10.3/4.3/60	24.7/4.2/20°	14/3.2/60°	15.1/3.2/20°
BW	42 KHz	16 KHz	16 KHz	16 KHz
Scan Time	6:19 mins	15 mins	8:38 mins	9:13 mins

For the calcaneus and tibia, scan times were around 6 minutes. In FIESTA acquisitions BW/ α was 16 KHz/65° at 1.5T and 16 KHz/60° at 3.0T. FGRE acquisitions had BW/ α of 16 KHz/20° at both 1.5T and 3.0T.All the images were corrected for coil intensity variations with an in-house algorithm prior to SNR measurements. SNR efficiency was computed as SNR divided by the square root of acquisition time.

Results:

Images acquired with the FIESTA protocol had significantly higher ($p<.05$) SNR efficiencies at both 1.5T and 3T and showed excellent detail. Comparative images are shown in Fig. 2. Mean ratios of SNR efficiencies from comparative FIESTA and FGRE scans are plotted in Fig3. As expected 3T affords a boost in SNR; however an accurate assessment of this SNR increase was not possible because of the differences in the 1.5 T and 3.0 T receiver coils.

Fig 2A **Fig 2B** **Fig 2C** **Fig 2D** **Fig 3**



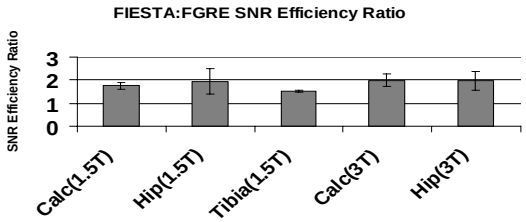


Fig 2A, 2B: Comparative FIESTA and FGRE scan of hip at 3T.Fig 2C, 2D: Comparative FIESTA and FGRE scan of tibia at 1.5T.Fig3 is a plot of the mean ratio of SNR efficiencies for each anatomical site at 1.5T and 3T.

Discussion:

Banding effect due to off-resonance was not observed in the acquired FIESTA images. Susceptibility effects in trabecular bone at 3.0T will be investigated. Because of its high SNR efficiency FIESTA is a promising technique for study of trabecular micro-architecture. FIESTA coupled with the parallel imaging and the added SNR at 3.0 T may allow rapid imaging of trabecular micro-elements at very high resolutions and with high signal yield.

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Reference:

1. Yuval Zur et al-An analysis of Fast Imaging Sequences with Steady-State Transverse Magnetization refocusing, MRM 1988 Vol-6:175-193
2. Brian A. Hargreaves et al-Characterization and Reduction of the Transient Response in Steady-State MR MRM 2001 Vol-46:149-158
3. S.Majumdar et al-High resolution MR: three dimensional trabecular bone architecture and biomechanical properties, Bone 1998, Vol 22:445
4. Ma J et al-Fast 3D large-angle spin-echo imaging MRM 1996Vol-35:903-10
5.E. Han et al-In vivo T1 and T2 Measurements of Muscoskeletal Tissue at 3T and 1.5 T-Proc. Intl Soc. Mag. Reson. Med 11:450