Relative Performance of FLASE, TrueFISP and Gradient Echo in µ-MRI of Trabecular Bone

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Introduction

In vivo MR micro-imaging (µ-MRI) is now feasible and has shown promise as a means to assess the structural integrity of trabecular bone (TB). Two different technical approaches have been used for this application: conventional 3D gradient echo (GE) (1) and FLASE (Fast 3D Large-Angle Spin-Echo) (2). The latter was found to be advantageous in that it is not sensitive to intensity distortions arising from local field gradients near the TB-marrow interface, caused by the greater diamagnetism of bone relative to bone marrow (3). Another potential approach is 3D TrueFISP which, as has been shown recently, has spin-echo like properties within a limited range of dephasing angles (4). In this preliminary work we investigate and compare FLASE, TrueFISP and refocused gradient echo pulse sequences in terms of their efficiency (SNR/unit time) and their ability to demonstrate microarchitectural features in intact human TB.

Method

The experiments were done on a 1.5 Tesla Siemens Sonata system, on two intact human distal radii (a 67 year old white female) fixed in formalin (10%), with a dedicated transmit/receive birdcage coil. All images were acquired at the same matrix size of 512x384x32 and a voxel size of 137x137x410 µm; TE/ TR = 9.5/ 80 ms for FLASE, 7.9/ 15.8 ms for TrueFISP and 8.2/ 17 ms for refocused gradient echo (r-GE), which employs phase encoding rewinders and a killer gradient along the read direction. All sequences used their optimum flip angles for the chosen TR. The echo time of the r-GE sequence was matched to that of TrueFISP. For TrueFISP and the r-GE sequence, images were acquired with 5 averages to achieve approximately the same total scan time as that of FLASE sequence (~16min). TB thickness was evaluated using the Fuzzy Distance Transform (FDT) method (5) which allows measurement of structural thickness in the limited resolution regime of in vivo µ-MRI. For the purpose of the TB thickness measurement, a longer scan for the r-GE was prescribed in one of the bone specimen to achieve SNR~8. SNR measurement were also performed in edible oil (mimicking fatty marrow) and doped water (to yield T1 and T2 similar to fatty marrow, T1~200 ms, T2~50 ms).

Results and Discussion

Images acquired from FLASE, TrueFISP and r-GE sequence are shown in Figure 1. The experimental data indicate SNR to be highest in FLASE (14.5), followed by TrueFISP (8.0) and r-GE (3.7). Measured SNR in TB, oil and water along with TB thickness for the three sequences are listed in Table 1. Image processing based measurements further suggest slightly greater apparent TB thickness in TrueFISP compared to FLASE in both specimens (average +6.5%), in contrast to that of the gradient echo (+12%). The similarity of TB thickness between TrueFISP and FLASE suggests TrueFISP to be less sensitive to phase dispersion than would be expected in a gradient-echo-type pulse sequence and confirms its spin-echo-like properties (4). For the targeted application it is noted that FLASE outperforms TrueFISP which, in turn, is more efficient than the r-GE.

Table 1 Summary of experimental data

	SNR			TB thickness (µm)	
	Bone	Oil	Water	Radius 1	Radius 2
FLASE	14.5	21	29	130.2	128.9
TrueFISP	8	11.2	17.4	134.6	141.7
r-GE	3.7	5.14	10.58	N/A	144.3

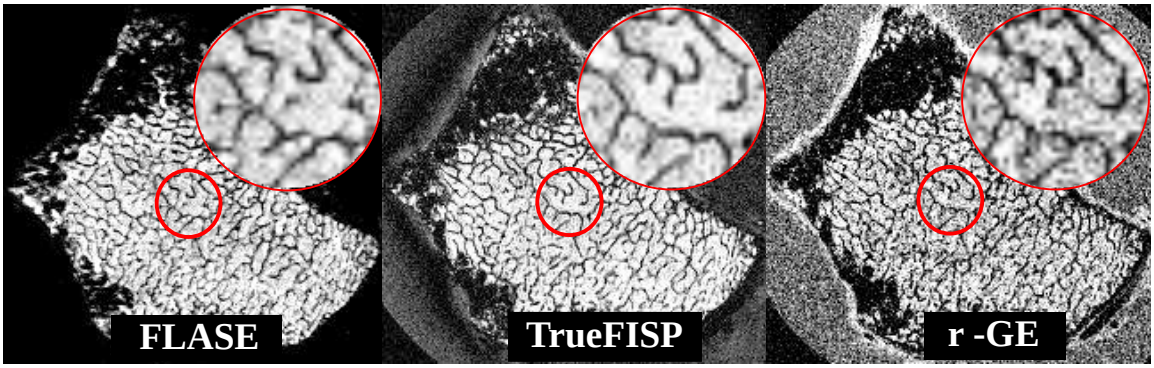

Fig 1. µ-MRI of intact human distal radius obtained with three pulse sequences in the same total time. Inset represents magnification of a circular ROI showing high similarity in structure. Note increase in apparent trabecular thickness in r-GE (see Table 1 above).

Conclusions

Unlike the gradient echo, the TrueFISP images show only minor broadening of trabeculae due to local susceptibility gradients, thus corroborating its spin-echo like properties. Although TrueFISP is potentially promising since it is widely available on state-of-the art equipment, in vivo scanning is hampered by gradient limitations. These limitations become significant at the voxel size required for µ-MRI of TB, putting very high demands on gradient amplitudes and duty cycle. In conclusion, these preliminary data suggest for efficiency in terms of SNR per unit time; FLASE>TrueFISP>>GE while for apparent structural thickness; FLASE<TrueFISP<GE.

References

1. Link TM et al, JBMR 13:1175-1182 (1998). 2. Ma J et al., MRM 35: 903-910 (1996). 3. Hopkins JA and Wehrli FW, MRM 37: 494-500 (1997).
4. Scheffler K and Hennig J, MRM 49:395-397 (2003). 5. Saha PK et al, CVIU 86:171-190 (2002).