MR Sequences for In-Vivo Trabecular Bone Imaging at 3 Tesla: Comparison with In-Vivo Micro-CT

R. Krug[1], J. Carbadillo-Gamiio[1], A. J. Burghardt[1], B. Hyun[1], S. Banerjee[1,2], G. Kazakia[1], M. Huber[1], T. M. Link[1], and S. Majumdar[1,2]

[1]Radiology, University of California in San Francisco, San Francisco, California, United States, [2]Joint Graduate Program in Bioengineering, University of California San Francisco - University of California Berkeley, CA, United States

Introduction

Which MR pulse sequence suits best for trabecular bone imaging is still a topic of research. Recently, a new fully balanced steady state spin-echo based MR sequence (bSSSE) was developed for imaging the trabecular bone structure in-vivo (1). With the advent of new computed tomography (CT) techniques, it is now possible to compare these MR sequences with high-resolution 3D peripheral quantitative micro-CT (3D-pQCT) in-vivo. To this end, the radius of 5 volunteers were imaged using two commonly used MR pulse sequences along wit the recently introduced bSSSE sequence. In order to analyze identical regions of interest, all images were registered. Structural bone parameters were then compared with and without registration. Additional comparisons were conducted using tibia and radius specimens. The impact of three different rotation angles on the bone parameters was investigated.

Material and Methods

The distal readius of 5 volunteers was imaged on a 3T Signa MRI system (General Electric, Milwaukee, WI) using 3 different MR pulse sequences (Table 1). The signal was detected using a transmit/receive quadrature wrist coil optimized for high-resolution musculoskeletal imaging (Mayo Foundation for Medical Education and Research, Rochester, MN). A coronal scout view was used to position the reference line at the distal endplate. The imaged volume was centered 14 mm (radius) and 27 mm (tibia) proximal to the reference position. For comparisons, an optimized fully balanced steady state free precession (bSSFP) sequence with two acquisitions and a standard fast gradient recalled echo (FGRE) were used. These sequences were further compared with the new bSSSE sequence. (see Table 1 for scanning parameters). The imaging time was less than 9 minutes for each sequence. Number of excitations and field of view (FOV) in phase direction were adjusted to yield the same imaging time. For MRI, the in-plane resolution was 156.25 µm with a slice thickness of 500 µm. After image acquisition, previously described methods were used to compute the apparent trabecular structural parameters such as apparent bone-volume over total-volume fraction (BV/TV), apparent trabecular plate separation (Tb.Sp), apparent trabecular plate thickness (Tb.Th) and apparent trabecular plate number (Tb.N). Additionally, 5 tibia specimen were rotated relative to the main magnetic field using 3 different rotation angles (0,10 and 20 degrees) and the structural bone parameters were determined each time using all 3 sequences. Following the MR scan, each volunteer was imaged using a peripheral CT system (XtremeCT, Scanco Medical, Bassersdorf Switzerland) with an isotropic voxel size of 82 µm. A coronal scout view was used to position the reference line and imaging volume similar to MRI for the radius. The corresponding bone within the volume of interest was segmented using a threshold-based algorithm. After having registered the images with MR, structural bone parameters were derived using the same methods (2) and region of interests.

Table 1: Pulse sequence parameters for bSSFP at 3T

Parameters	*bSSSE*	*bSSFP*	*FGRE*
TR/TE/Flip [ms/ms/degrees]	67 / 10 / 120	14.2 / 2.9 / 60	12.1 /3.1 / 40
Bandwidth [kHz]	± 15.63	± 31.25	± 31.25
NEX	1	2	4

Table 2: Correlations with pQCT determined for each sequence

Correlation CT	*BV/TV*	*TbN*	*TbSp*	*TbTh*
bSSSE	0.60	0.94	0.75	0.62
FGRE	0.62	0.95	0.79	0.71
bSSFP	0.74	0.98	0.98	0.46

Results and Discussion

Images using pQCT and MRI are depicted in Figure 1. Correlations for the different structural bone parameters compared with pQCT are shown in Table 2. The highest correlation was found for the trabecular number for all sequences. A good correlation was also found for TbSp and less forBV.TV and TbTh. The largest difference in parameters were found for TbTh (30-55% increase compared to pQCT). TbN were very similar for both modalities (,10% difference between MR and pQCT). Differences between correlation of registered and non-registered pQCT images were found to be not significant. The variability of bone parameters using different rotations in respect to B0 were <5.6% and thus in the order of the variability between baseline and follow-up scan.

In this work we evaluated MR pulse sequences for imaging of the trabecular bone in-vivo. We compared the performance of each sequence with a new in-vivo pQCT device. The new bSSSE sequence revealed highest correlation for trabecular thickness. This was expected, since spin-echo based sequence do not introduce additional broadening of the trabeculae due to susceptibility differences. Trabecular number was best correlated using bSSFP. This is explained by the same effect. Since this sequence is more prone to off-resonance effects, the trabeculae are more pronounced (thicker) and small trabeculae which usually disappear due to partial volume effects, are still depicted.

Acknowledgement: This work is funded by NIH grant award program number RO1AR17762

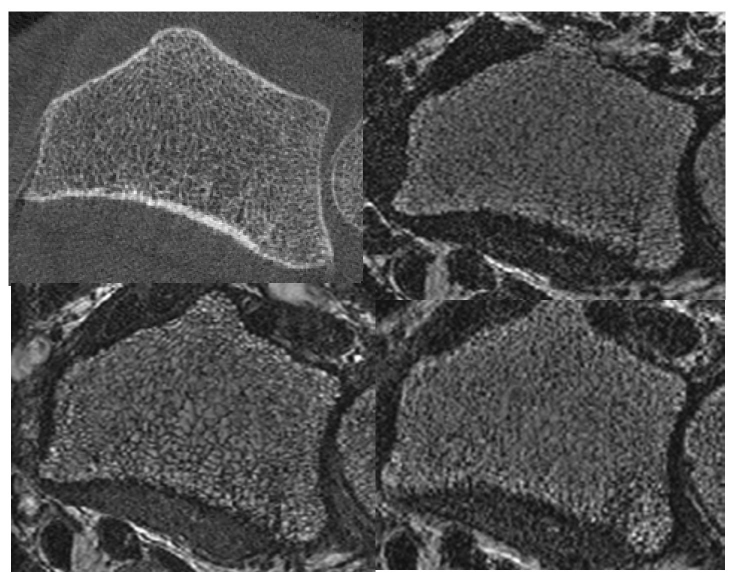

Figure 1: Depiction of the distal radius using pQCT (top-left), bSSSE (top-right), FGRE (buttom-right) and bSSFP (bottom-left)

References

1. Krug R, Han ET, Banerjee S, Majumdar S. Fully balanced steady-state 3D-spin-echo (bSSSE) imaging at 3 Tesla. Magn Reson Med 2006;56(5):1033-1040.
2. Majumdar S, Genant HK. Assessment of trabecular structure using high resolution magnetic resonance imaging. Stud Health Technol Inform 1997;40:81-96.