In-Vivo Trabecular Bone Imaging at 7 Tesla

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Introduction

We showed in previous work that high-field MRI at 3T is suitable for imaging the structure of trabecular bone non-invasively and in-vivo(1). In this work we have further investigated trabecular bone imaging at a higher field strength of 7T in-vivo. The distal tibia of 6 volunteers was imaged using MRI at 3T and 7T. Additionally, the volunteers were imaged using a new in-vivo 3d peripheral quantitative micro-CT (3D-pQCT). In order to analyze the same region of interest, the images were registered. For both field strengths, a fully balanced steady state free precessions (bSSFP) pulse sequence and a parallel imaging technique was applied. Scanning parameters were optimized through numerical simulations of the Bloch equations. The signal to noise ratio was determined. Results from quantitative assessment of the trabecular bone structure were compared with 3 Tesla and with in-vivo 3D-pQCT imaging.

Material and Methods

The distal tibia of 6 volunteers was imaged on a 7T and 3T Signa MRI system (General Electric, Milwaukee, WI). A four-coil dual phased array receiver coil Nova Medical (Wilmington, MA) was used at 3T and a transmit/receive quadrature coil with two elements (Nova Medical) at 7 T. Transmit gain and shimming were manually adjusted. A coronal scout view was used to position the reference line at the distal tibial endplate. The imaged volume was centered 27 mm proximal to the reference position. An optimized fully balanced steady state free precession (bSSFP) sequence with two acquisitions was used for high-resolution imaging of the trabecular bone structure at both field strengths (see Table 1 for scanning parameters). The imaging time was less than 10 minutes in both cases. 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).

Following the MR scan, each tibia was imaged using a peripheral CT system (XtremeCT, Scanco Medical) with an isotropic voxel resolution of 82 µm. A coronal scout view was used to position the reference line and imaging volume similar to MRI. The trabecular bone within the volume of interest was segmented using a threshold-based algorithm. After having registered the images, structural bone parameters were derived using the same regions of interest.

Parameters	*7 Tesla*	*3 Tesla*
TR/TE/Flip [ms/ms/degrees]	**13.1 / 2.8 / 40**	**13.9 / 2.9 / 60**
Bandwidth [kHz]	**± 31.25**	**± 31.25**
Voxel [um]	**156**	**156**
Grappa Reduction	**2**	**2**

Table 1: Pulse sequence parameters for bSSFP at 7T and 3T.

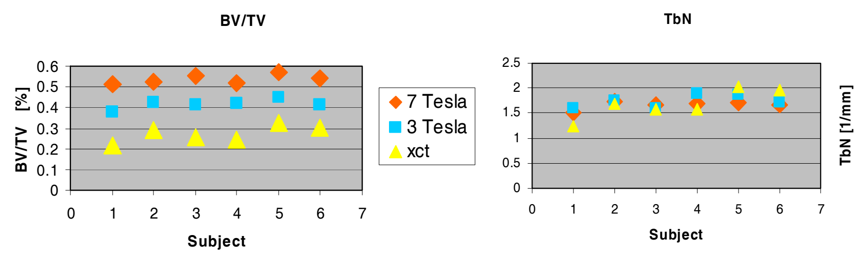

Figure 2: Results for bonefraction and trabecular number for all 3 modalities

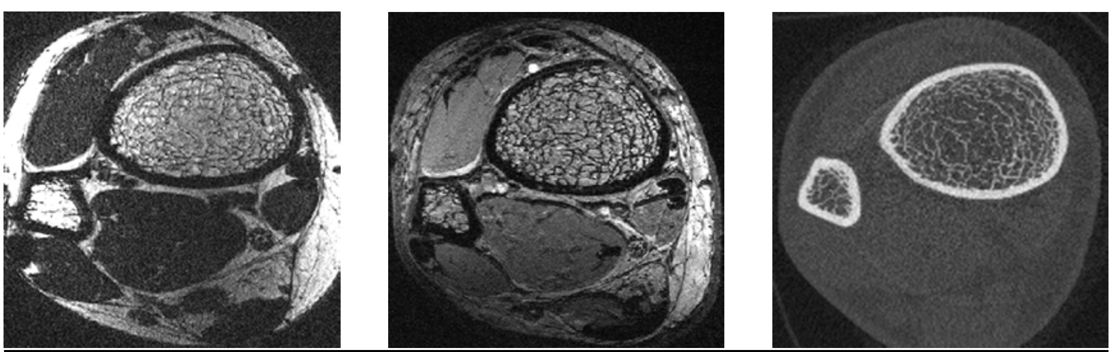

Figure 1: Images of the distal tibia are shown acquired with MRI at 3 Tesla (left), 7 Tesla (middle) and 3D-pQCT (left). The trabeculae are muchmore pronounced at the higher field strength as can be seen clearly from these images. Using 3D-pQCT the trabeculae appear with high signal in contrast to MRI where they deliver no signal.

Results and Discussion

Comparing the resulting structural parameters using MRI, the highest correlation found was for apparent BV/TV (R=0.73). Tb.Sp. and Tb. N yielded a slightly lower correlation (R=0.67 and R=0.60) and Tb.Th (R=0.41). The best correlation between 7T MRI and 3D-pQCT was found for Tb.SP (R=0.89) and lower for BV/TV (R=0.73) and Tb.N (R=0.69). Again we found a very low correlation for the trabecular thickness (R=.14). As expected did we find a significant difference in Tb.Th. The mean difference of Tb.Th. was 25% between the field strengths using MRI and >32% compared with CT (3D-pQCT revealing the smalles trabeculae and 7T the thickest trabeculae). The trabecular number is not significantly different (<4.3% difference). In this work we showed that high-field MRI at 7T field strength along with parallel imaging is suitable for trabecular bone imaging.in a reasonable clinical scan time. (<10 minutes). Measuring SNR, we found a significant increase using 7T compared to 3T. Considering the different rf-coils used (2 channel for 7T and 4 channel for 3T) as well as the increasing BV/TV at 7T (broadened trabeculae) we determined a two fold increase in SNR for the higher field strength.

References

1. Banerjee S, Han ET, Krug R, Newitt DC, Majumdar S. Application of refocused steady-state free-precession methods at 1.5 and 3 T to in vivo high-resolution MRI of trabecular bone: simulations and experiments. J Magn Reson Imaging 2005;21(6):818-825.

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