In vivo measurement of trabecular bone microarchitecture in the proximal femur with MRI at 1.5 T and 3 T

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Introduction

Osteoporosis is a skeletal disease characterized by low bone mass density (BMD) and micro architectural deterioration of bone tissue leading to an increase in bone fragility and susceptibility to fractures. Osteoporotic fractures of the hip represent a serious socioeconomic health problem that is expected to worsen as the size of the elderly population increases. Previous studies have demonstrated the important contributions of the microstructural distribution of trabecular bone to bone strength. Improved diagnostic tools for the non-invasive assessment of bone quality in the hip could provide better predictive measures of propensity to fracture as well as improved evaluation of the efficacy of treatment and preventative therapies. The focus of this work was to investigate the use of high resolution MRI to evaluate the trabecular bone structure in the proximal femur in vivo.

Material and Methods

MRI hip measurements of six volunteers (2 female and 4 male) were performed on 1.5 Tesla and 3 Tesla Signa systems (General Electric, Milwaukee, WI) using a four-coil phased array for detecting the signal. A 3D FIESTA (fast imaging employing steady-state acquisition) sequence was applied to obtain high resolution coronal images of the proximal femur using the parameters in Table 1. After manually defining a region of interest in the greater trochanter, a low-pass filter (LPF)-based coil sensitivity correction was conducted on this local region to correct the spatial variations in the detection coil sensitivity. The next post-processing step included binarization of the trochanter into bone and marrow phases. Previously described methods [1] were used to compute the apparent trabecular structural parameters: bone fraction (app.BV/TV), separation (app.Tb.Sp), thickness (app.Tb.Th) and number (app.Tb.N). Each volunteer was scanned twice on both 1.5 T and 3 T MRI systems to assess the reproducibility of the measurements. Ten slices of a total of 28 acquired slices were used for analysis. Reproducibility was calculated by means of the repeated measurement percent coefficient of variation (%CV), given by 100x the root mean square SD of the repeated measurements for each subject divided by the mean.

Parameter	*1.5 Tesla*	*3 Tesla*
TE/TR	10.3 / 4.2 ms	14 / 3.2 ms
Flip angle	60	60
Bandwidth	41.7 Hz/pix	15.63 Hz/pix
In plane resolution	0.234 mm	0.234 mm
Slice thickness	1.5 mm	1.5 mm
Imaging time	6'12"	8'37"

Table 1: Optimized FIESTA sequence parameters for 1.5 T and 3 T scans

Results

Typical high resolution images for both field strengths are depicted in Figure 1. The mean value and SD for app.BV/TV, app.Tb.N, app.Tb.Sp and app.Tb.Th obtained for all six volunteers at 1.5 T and 3 T are shown in Table 2. The range of values are in accordance with in vitro measurements from micro-computed tomography (microCT) [2]. Values for the coefficient of variation %CV were found to be in between 2-4% for 1.5 T and over 8% at 3 T.

Discussion

We have shown that it is possible to acquire high resolution MR images from the proximal femur in vivo at 1.5 T and 3 T. In a first study with six volunteers, reasonable results of ap.BV/TV, app.Tb.N, app.Tb.Sp and app.Tb.Th could be found for both field strengths. GRE type sequences are known to be affected by magnetic susceptibility variations, resulting in an apparent swelling of trabeculae. This may account for the changes in the trabecular structure parameters between 1.5 T and 3 T, as trabeculae appear thicker (increased Tb.Th at 3 T) and more small trabeculae are detected giving a larger Tb.N and smaller Tb.Sp. This increased sensitivity to smaller trabeculae may account for the decrease in reproducibility at 3T.

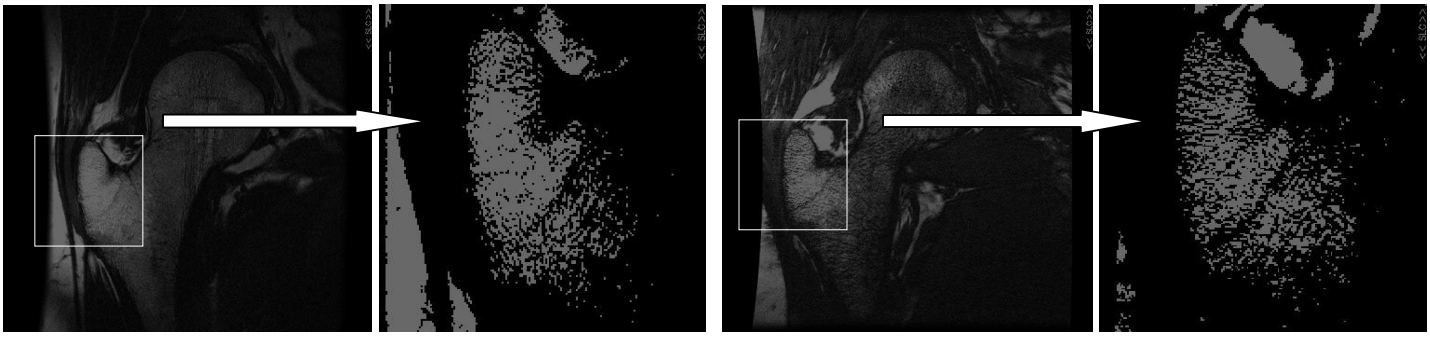

Figure 1: Typical high resolution FIESTA images from 1.5 T (left) and 3 T (right) MRI. The proximal femur is depicted with the region of interest within the trochanter. The binarized image of the trochanter is zoomed

	app.BV/TV [mm]	*app.Tb.N [1/mm]*	*app.Tb.Sp [mm]*	*app.Tb.Th [mm]*
Mean (SD) at 1.5 T	0.212 (0.033)	0.790 (0.113)	1.006 (0.159)	0.270 (0.032)
Mean (SD) at 3 T	0.367 (0.062)	1.159 (0.100)	0.535 (0.122)	0.335 (0.078)

Table 2: Overall statistical reproducibility measures for trabecular structure parameters from 1.5 T and 3 T images

References

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