Advanced Image Analysis Techniques of New High-Resolution Images of teh Proximal Femur in the Presence of Red and Yellow Bone Marrow using Local Bone Enhancement Fuzzy Clustering

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Introduction

Osteoporotic fractures of the proximal femur are very common and often result in high rates of morbidity and mortality. Most osteoporotic fractures occur at locations that are rich in trabecular bone and there is increasing evidence that the trabecular and cortical bone architecture contributes significantly to bone strength[1]. MRI has emerged as one of the leading *in vivo* methods for non-invasive imaging of the trabecular bone microstructure at peripheral sites. However, *in vivo* high resolution imaging of deeper sited regions like the proximal femur is more challenging[2]. Thus, images of the proximal femur with high spatial resolution (in particular slice thickness) have previously not been acquired in a clinically reasonable scan time with sufficient signal-to-noise ratio (SNR). Furthermore, the presence of red and yellow bone marrow (Figure 1) is unique to the femur and requires enhanced image processing methods in order to separate both marrow phases from the bone. The goal of this abstract was two-fold; firstly, to acquire *in vivo* images of the proximal femur with high spatial resolution and SNR in a clinically feasible scan time as previously only accomplished at peripheral sites using recent enhancements in scanner and coil technology. Secondly, to evaluate the feasibility of trabecular bone analysis in the presence of red and yellow marrow in the deep seated femoral head using a novel approach to trabecular bone segmentation termed bone enhancement fuzzy clustering (BE-FCM).

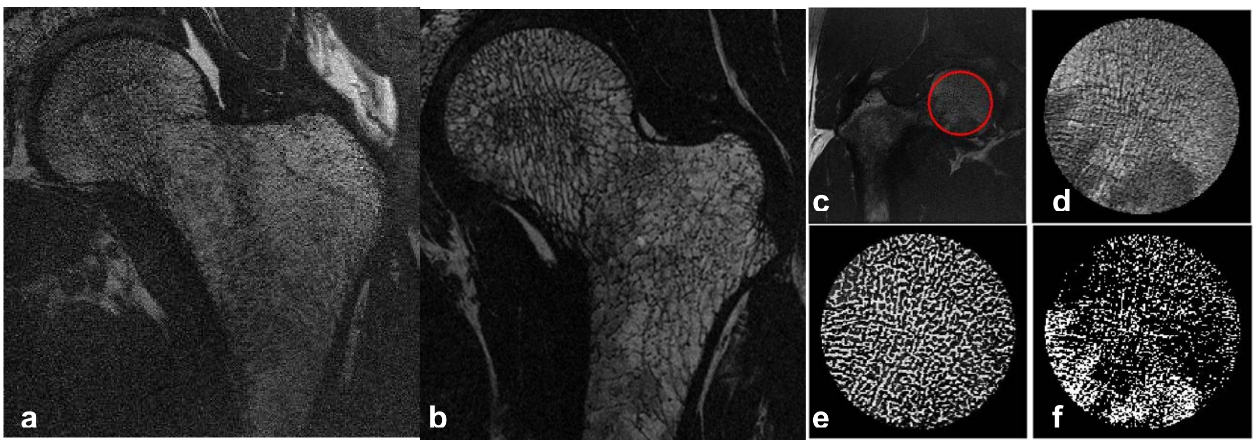

Figure 1: a) Image of the proximal femur using a previous acquisition protocol[2]. b) New high-resolution image of the proximal femur. Hemopoietic or red marrow is composed of ~40% water (longer T1) and appears dark (femoral head, neck and shaft). The more prevalent yellow marrow is more fatty and gives a brighter MR signal. c) ROI defined in the femoral head. d) The ROI in c). e) Trabecular bone segmentation of the ROI in c) and d) segmented using BE-FCM. f) The same ROI segmented using an established dual thresholding technique.

Material and Methods

High-resolution images of 14 proximal femurs (13 females, mean age 41±14 years) were acquired on a 3T GE MR750 system using an 8 channel phased array coil and a fully balanced steady state free precession pulse sequence (TR/TE 8.6ms/3.09ms, flip angle 60º, bandwidth ±62.5 kHz, voxel size 0.23×0.23×0.5 mm). Scan time was 12 minutes. A spherical region of interest (ROI) was defined semi-automatically, and trabecular bone was segmented using dual thresholding[2], and a novel partial membership technique, BE-FCM[3], which allows for extraction of multi-scale local structural information of the trabecular bone network without thresholding the image.

Results and Discussion

Figure 1 demonstrates the superior image quality of the new high-resolution images (1b) compared to previous acquisitions (1a), making analysis of the femoral head feasible. Using new hardware technology, SNR measurements revealed a substantial gain in SNR of 1.7 (trochanter) and 3.0 (head) from previous measurements[2] in a similar scan time. Additionally, the local structure information gain in BE-FCM results in a superior trabecular bone segmentation compared to dual thresholding in the presence of red and yellow marrow (Figure 1c-f). The mean apparent bone fraction was 0.27 (±0.01) with BE-FCM and 0.50 (±0.04) with thresholding, which is significantly higher ($p<10^{-10}$).

The enhanced MR hardware is shown to enable acquisition of high resolution images of the proximal femur with unprecedented spatial resolution in a clinically reasonable scan time. We also showed that BE-FCM allows for segmentation of the trabecular bone structure in the presence of red and yellow bone marrow whereas conventional thresholding fails. The demonstrated improvements in image quality and analysis allows for *in vivo* trabecular bone analysis of the entire proximal femur including the femoral head, which makes the framework potentially very interesting in fracture prediction analysis throughout the proximal femur[4].

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References

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