Correction of Coil Induced Intensity Inhomogeneities in Magnetic Resonance for Trabecular Bone Analysis

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Introduction

Osteoporosis is a degenerative disease characterized by bone loss, and it is associated with significant socioeconomic impact [1]. Trabecular bone analysis is important in clinical studies of osteoporosis, and magnetic resonance imaging (MRI) allows for non-invasive 3D quantitative trabecular bone assessment.
MRI of osteoporosis-related anatomical locations are generally acquired with a surface coil in order to obtain sufficient sensitivity and resolution for quantification of the trabeculae, however these coils introduces intensity inhomogeneities which affect the analysis of the trabecular bone structure. An analytical computation of such bias fields can be obtained given coil size and positioning, but with complex interactions between typically at least four channels in the surface coils routinely used for MRI of trabecular bone such an estimation may not be sufficiently accurate. Currently, techniques such as low-pass filtering (LPF) are employed for coil correction [2], however such a technique assumes that the mean intensity is constant across the image and is therefore subject to edge artifacts. This work evaluates the applicability of a fully automatic coil correction by nonparametric nonuniform intensity normalization (N3) in the analysis of trabecular bone parameters in comparison to LPF coil correction, both by correlation between coil corrected data acquired with a surface coil to homogeneous data *ex vivo* and inter-scan reproducibility *in vivo*.

Materials and Methods

The proximal femur is one of the most important sites in osteoporotic fracture studies, and the feasibility of trabecular bone analysis at this site has recently been demonstrated [3]. MRI scans of six cadaveric femur specimens (4 females, mean age at death 86±6 years) were acquired coronally using a high-field 3T GE Signa scanner with a FIESTA-C sequence, TR/TE 11.7 ms/4.6 ms, flip angle 60º, bandwidth ±31.25 kHz, and voxel size 0.23×0.23×1.0 mm³. In order to simulate *in vivo* conditions, the specimens were embedded in a soft-tissue environment in a cylindrical phantom containing bovine muscles and fat [4]. Each specimen was scanned twice; once with a four-element phased array coil (SC) routinely used for MRI in trabecular bone studies, and once with a volumetric coil (VC) which was used as gold standard due to its homogeneous intensity profile (Fig. 1). The N3 method iteratively sharpens the image histogram and models the bias field using smooth b-splines [5]. Coil correction using LPF and N3 was performed on the SC scans and the following trabecular bone parameters were calculated in manually defined regions of interest (ROI) within the trochanter: mean bone volume fraction (BV/TV), apparent trabecular thickness (Tb.TH), apparent trabecular number (Tb.N), and apparent trabecular separation (Tb.SP) as described in [2]. In addition, 6 healthy young males were repeatedly scanned *in vivo* using the same scan parameters in order to evaluate the effect of inter-scan reproducibility of the bone parameters when preprocessed with the LPF vs. N3 methods (Fig. 3).

Fig. 1. Coronal slices from MRI femur scans acquired with VC (left), SC (middle), and SC corrected with N3 (right). Trabecular bone is represented by signal void inside the femur.

Results

In the *ex vivo* study, the bone parameters from SC data processed with LPF, N3 coil correction method, and no preprocessing (Raw) were correlated with corresponding values obtained from VC data (Table 1). An example of VC and SC data, along with SC data corrected with N3 can be seen in Fig. 1. A close-up comparison of the bias fields estimated with LPF and N3 around the trochanter ROI can be seen in Fig. 2. In the *in vivo* study, the inter-scan variability was 7.7-10.2% (mean CV) for the four trabecular parameters when the scans were coil corrected using LPF. The corresponding values were 2.8-6.6% using N3 coil correction.

	BV/TV	Tb.N	Tb.Sp	Tb.Th
Raw	0.97**	0.35	0.73	0.41
LPF	0.83*	0.87*	0.89*	0.33
N3	0.95**	0.94**	0.96**	0.82*

Table 1. Correlations between SC and VC data. *p<0.05, **p<0.005

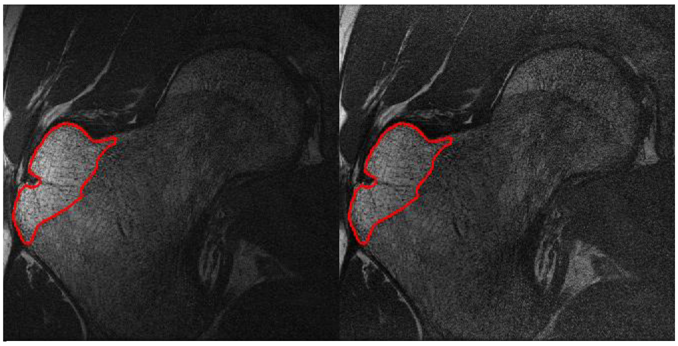

Fig. 3. Slice from *in vivo* MR scan of the hip (left), same slice N3 coil corrected (right), the trochanter ROI is delineated in red.

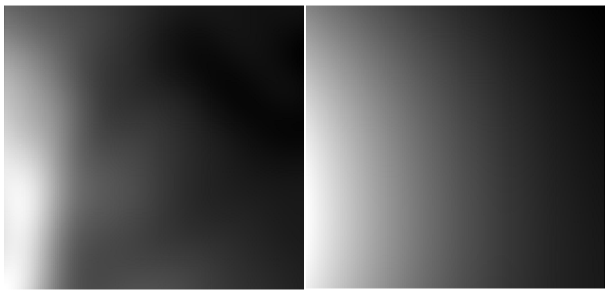

Fig. 2. Close-up of bias fields estimated by LPF (left), and N3 coil coil correction (right).

Discussion

The MRI acquisitions of femur specimens using the same scan parameters but different coils allows for an evaluation of the influence of intensity inhomogeneities on the trabecular bone parameters without any major confounding factors. While both coil correction methods improve the correlations between SC and VC data in the *ex vivo* study compared to the raw intensity values, the N3 method outperforms LPF with more significant correlations. In Fig. 2 it can be seen that the N3 bias field estimate is less sensitive to edge artifacts compared to LPF. The *in vivo* study showed that the reproducibility of the bone parameters was also improved by using the N3 coil correction method. Along with short run time and operator independence, these results suggest that the N3 method can become a valuable tool in trabecular bone analysis from MRI data.

References

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