Accuracy in trabecular bone structural measurement from high-resolution images acquired with GRAPPA-based parallel imaging

B. Hyun[1], S. Banerjee[1,2], and S. Majumdar[1,2]

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

Introduction:

High resolution MRI of the micro-architecture of trabecular bone is an effective tool for monitoring changes in bone structure associated with osteoporosis. Given the long measurement time (15-20 mins) generally involved in these scans, patient motion during the acquisition often results in blur and distortion artifacts in the image directly affecting the measurement accuracy of bone structural metrics from the images. While navigator methods have previously been applied to track and correct for patient motion, partially parallel acquisition (PPA) can reduce the incidence of patient motion by effectively reducing the scan time. The feasibility of GRAPPA-based parallel imaging[1,2] for HR-MRI of trabecular been has been demonstrated in previous works. The purpose of this study was to assess the fidelity of measurement of all the commonly used bone structural metrics analogous to histomorphometry from the parallel-reconstructed images.

Methods:

High-resolution MR acquisitions were conducted at the non-dominant distal radius of five volunteers, using a 3T GE Signa Echospeed system (GE Healthcare, WI) and an eight-channel array (GE Research) for signal reception. A three-dimensional multiple acquisition SSFP sequence 3D FIESTAc (cycled Fast Imaging employing Steady State Acquistion) was employed with the following acquisition parameters: TE/TR = 4.64/17 ms, Flip = 60^0, BW = 31.25 kHz, and Matrix = 512x384x54 (156^2 x 500 um^3) and scan time ~ 12 minutes. Parallel acquisitions were employed with a modified FIESTAc sequence with undersampling by a factor of 2 and 12 auto-calibration lines in the central k-space. Additionally, an R=3 scan was conducted in one subject. Scan times for the R=2 and R=3 scans were 6:20 min and 4 min respectively. To examine the reproducibility of measurements obtained from the accelerated scans, a repeat R=2 scan was conducted in 1 subject after re-positioning. All images were reconstructed off-line on a Sun Workstation (Sun Microsystems, Mountain View, CA) using in-house reconstruction routines programmed in Matlab (MathWorks, USA). Undersampled datasets were reconstructed using a customized GRAPPA-based reconstruction algorithm [2]. Images were post-processed to correct for coil intensity variations. The trabecular bone compartments of the images were then segmented, semi-automatically, and 2D histomorphometry-based analysis was conducted to calculate App. BV/TV (apparent bone volume fraction), App. Tb.N (apparent trabecular number), App. Tb.Sp (apparent trabecular spacing), and App. Tb.Th (apparent trabecular spacing). The measures were averaged in 5mm slabs along the slice direction, 14mm from the endplate position, using in-house routines written in IDL (RSI Boulder, CO)[3].

Results:

Accelerated images had very similar bone structural depiction as the unaccelerated images, as seen in Figure 1. The average absolute percent differences between unaccelerated and R=2 images are shown in Table 1. The App. TbN values for all slice locations measured from an R=1 and corresponding R=2 image set are plotted in Figure 2. For the reproducibility experiment, the coefficients of variation were found to be 2.98%, 1.17%, 1.42%, and 4.14% for App. BV/TV, App. Tb.N, App. Tb.Sp, and App. Tb.Th respectively. In the consecutive slab the CV was found to be 0.82%, 1.61%, 1.01%, and 2.44% for App. BV/TV, App. Tb.N, App. Tb.Sp, and App. Tb.Th respectively.

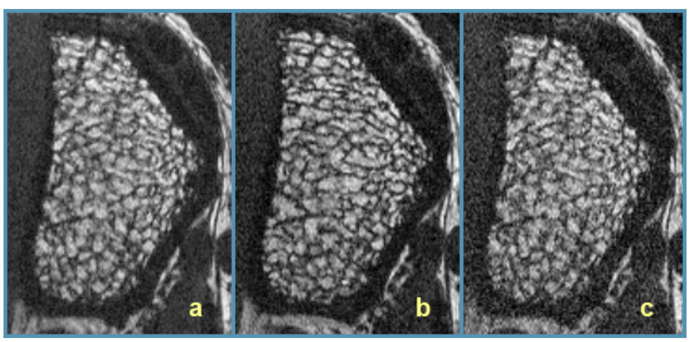
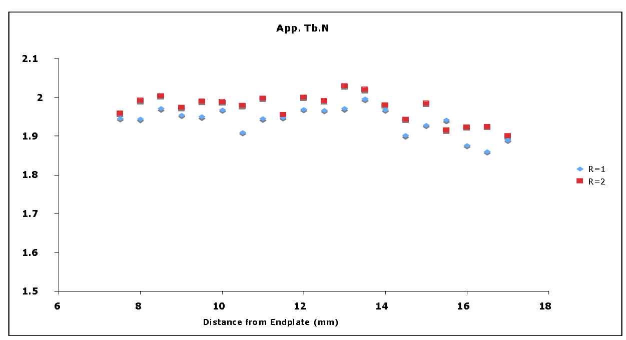


Figure 1. Axial Radius image a) R=1, b) R=2, c) R=3

Table 1: Percent absolute differences in bone measures between R=1 and R=2

Endplate Distance	App. BV/TV	App. Tb.N	App. Tb.Sp	App. Tb.Th
7 - 12 mm	2.14±2.10	3.32±1.51	4.61±2.60	2.30±0.92
12 - 17 mm	4.66±3.93	2.22±1.67	5.23±4.54	4.86±2.46

Figure 2. Plot of App. Tb.N values from R=1 and R=2 images for each slice location



Discussion:

Although the bone structural measurements from the accelerated datasets showed some overestimation (Figure 2), the deviation in measurements from R=1 datasets were mostly within acceptable range of variability. Measurements from the accelerated scans also showed high reproducibility. However, the parallel reconstruction showed increased sensitivity to flow artifacts in image regions of interest. Incorporation of acceleration in the scans yield reasonably short scan times (4-6 minutes) which can help reduce the incidence of motion-induced artifacts and increase flexibility in protocol design.

References:

1. Griswold et al., Magn Reson Med. 2000 Oct;44(4):602-9
2. Banerjee et al., Magn Reson Med. 2006 Nov;56(5):1075-84
3. Newitt DC et al., Osteoporos Int. 2002;13(4):278-87