Parallel Imaging of trabecular bone micro-architecture using Autocalibrating technique at 3 T

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Introduction: The field of partially parallel imaging (PPI) has seen tremendous progress in recent years. However the application of PPI to small field of view (FOV) high resolution (HR) imaging has not been well evaluated.HR applications such as MRI of trabecular bone micro-architecture can benefit tremendously from PPI by reduction in scan time or increase in volume coverage or spatial resolution in the standard acquisition time. In order to evaluate its true efficacy it is important to investigate the effects of PPI on depiction of small structures and their quantification in the resulting images. In this study we implemented 3D Cartesian autocalibrating (AC) acquisition and a GRAPPA [1] based parallel reconstruction with robust data fitting and applied it to imaging of trabecular bone micro architecture with a multiple acquisition steady state free precession (SSFP) [2] sequence at 3 Tesla (T). Characterization and quantitative analyses of parallel images were performed and the role of PPI in improving Signal to Noise Ratio (SNR) efficiency in multiple SSFP was investigated.

Methods: Several data fitting variants of regular GRAPPA reconstruction were programmed in MATLAB (MathWorks, USA) and tested on full FOV datasets decimated to simulate several reduction/acceleration factors (R) and 8-12 training blocks. A GRAPPA based technique with multi-column floating node fitting (MC-FNF) [3] of source lines to AC lines for segments along the readout direction was chosen as optimal, based on minimum artifact power**.** The three dimensional multiple acquisition SSFP sequence 3D FIESTAc (cycled Fast Imaging employing Steady State Acquisition) was modified to incorporate Cartesian variable density sampling in the phase-encoding direction. The maximum feasible reduction factor in each encoding direction of the coils was examined by principal component analysis (PCA) of coil sensitivity images [4]. Three volunteers each were scanned on the 3 T GE Signa Echospeed system (GE Healthcare) at the sites of the hip (proximal femur) and the knee (distal femur) with a custom built eight channel dual phased array coil and at the site of the ankle with an eight channel head array (Medical Devices, WI ,USA) respectively .Reduction factors of R=1,2, 3 and 4 were used in conjunction with the modified variable density 3D-FIESTAc imaging sequence with partial echo and 2 phase cycles. In-plane resolution of the images was 190 µm at the ankle and knee and 230 µm at the hip. Slice thickness was 500 µm at the ankle and 1000 µm at the knee and the hip. Scan time of full-FOV acquisition of a 16 slices knee dataset was 4 minutes 27 seconds, and of 32 slices ankle and hip datasets were 9 minutes 19 seconds and 6 minutes 45 seconds respectively. Resulting images were subjected to thresholding based analyses [5] for quantification of trabecular micro-structural parameters. Signal-to-noise ratio measurements and histogram and periodogram analyses were performed. To investigate the feasibility of using PPI to increase the SNR efficiency of multiple acquisition phase-cycled SSFP, two volunteers were scanned at the site of the hip, once with R = 1 and 2 phase cycles (6 minutes 45 seconds) and once with R=2 and 3 phase cycles (5 minutes 17 seconds). Images in this second case were combined across the phase-cycles by sum-of-squares. In all 2 phase cycle acquisitions, a maximum intensity projection across the phase cycles was computed [2].

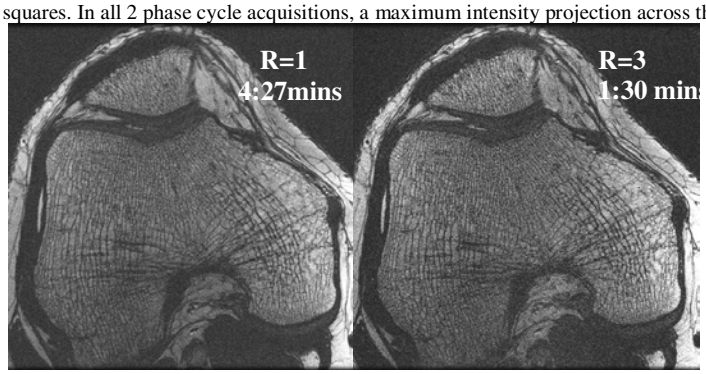

Figure 1a Figure 1b

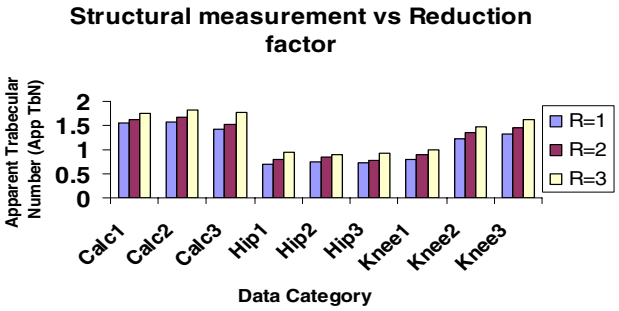

Figure 2

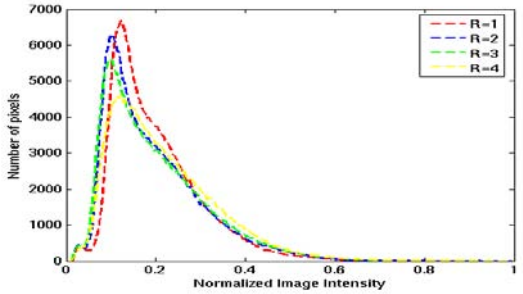

Figure 3

Results:
Images preserved visualization of trabecular microstructures even for higher reduction factors (Fig 1) but in some datasets image quality was degraded at R=4 due to local noise enhancement which might be expected since the maximum feasible R in the phase-encoding direction was found to be 4 for both the coils. Spatial periodogram of images with different reduction factors showed slight increase in lower frequency energy at higher reduction factor (R=4), so the spatial autocorrelation and resolution of full FOV images seem to be preserved to a large extent. Quantitative analyses showed an increase in structural measures such as apparent trabecular number (App. TbN) (Fig 2) and apparent bone fraction (BF) with increase in R which can be partly due to loss of SNR and partly due to the leftward shift in the peak position and asymmetric broadening to the right of the image intensity histogram with increasing R (Fig 3) .In the SNR efficiency comparison scans, a 18% increase in SNR efficiency was recorded for PPI acquisition compared to standard acquisition

Discussion:
This is the first time PPI technique for HR-MRI of trabecular bone has been demonstrated. While the depiction of microstructures was preserved in parallel images till R=3, their accurate quantification may require new analysis techniques that are independent of the background signal [6]. The study also showed the possibility of improving SNR efficiency in multiple acquisition SSFP imaging by employment of PPI technique. PPI for HR-MRI may be used to increase through-plane coverage while maintaining reasonable scan time and reasonable SNR. In clinical protocols employing 14-18 minutes it can be used to reduce acquisition time.

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