Autocalibrating Parallel Imaging at 7T-high resolution, quantitative and phase-sensitive applications

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Introduction: The synergy between high field strength and parallel imaging has been discussed in the literature [1]. In this study we present our preliminary work on implementation of Autocalibrating Partially Parallel Imaging (PPI) at 7 Tesla (General Electric Signa scanner) Here we look at three different applications: high resolution (HR) imaging of trabecular bone microarchitecture, quantitative imaging of cartilage and susceptibility weighted imaging (SWI) of brain vasculature.

Method: A Generalized Autocalibrating Partially Parallel Acquisition (GRAPPA) [2] based reconstruction algorithm using multi-column floating node fitting (MC-FNF) [3] of source lines to auto calibrating (AC) lines for segments along the readout direction was programmed in MATLAB (MathWorks, USA). Floating node fitting allows adequate number of data fitting combinations at higher reduction factors without acquisition of a large number of AC lines. Three dimensional (3D) gradient echo based sequences such as Spoiled Gradient Echo (SPGR), Fast Gradient Echo (FGRE) and Fast Imaging Employing Steady State Acquisition (FIESTA) were modified to incorporate Cartesian variable density sampling in the phase encoding direction. Trabecular microarchitecture was imaged at the site of the ankle in a volunteer with 3D FIESTA-c (cycled FIESTA) sequence with partial echo, 2 phase cycles, 512x384x32 acquisition matrix and with in plane resolution of 195 µm.The cartilage was imaged in a porcine specimen using the modified Fast SPGR (FSPGR) sequence. For SWI of brain, a volunteer was imaged with flow compensated GRE sequence. All the above acquisitions were performed for full field of view (FOV) as well as for R=2, 3 and 4 with 12-18 AC lines. A 16 channel phased array receiver coil (USA Instruments) was used in all the scans. Image reconstructions were performed offline on a Sun Workstation. In the porcine knee images, segmentation of the femoral cartilage and quantification of its thickness and volume was performed using a MATLAB software developed in our lab [4]. For the SWI application, phase masks were constructed from the reconstructed complex image data of each individual coil element and multiplied into the magnitude images followed by a sum of square reconstruction. [5] Additionally all parallel images were characterized for their spatial autocorrelation and resolution by periodogram technique.

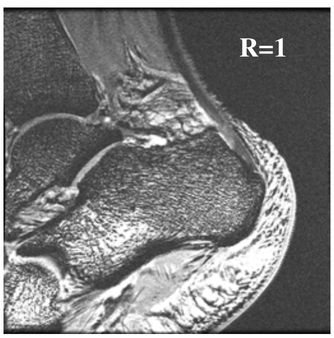

Figure 1 a

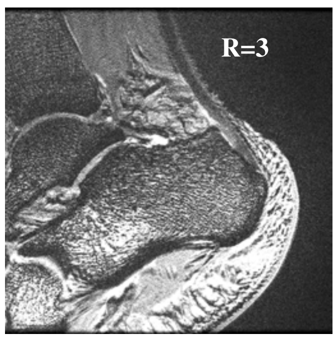

Figure 1b

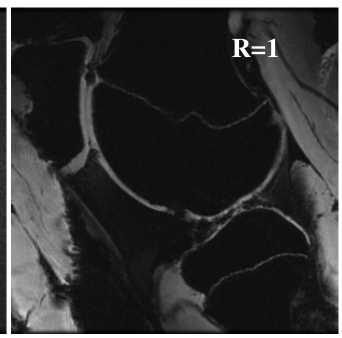

Figure 2a

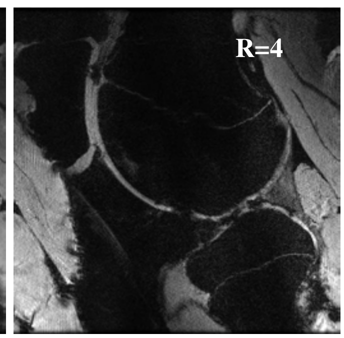

Figure 2b

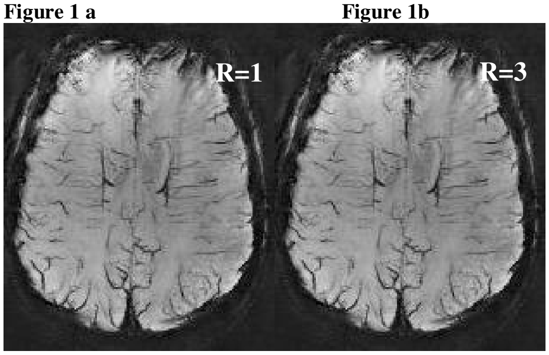

Figure 3a **Figure 3b**

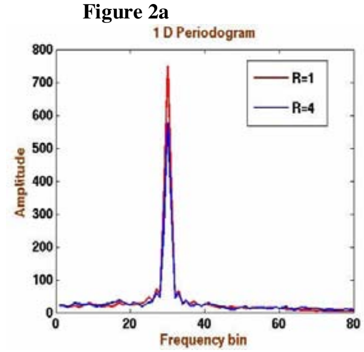

Figure 4

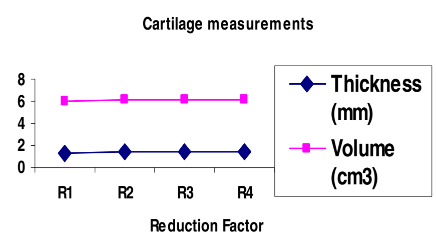

Figure 5

Results: Image quality in terms of visualization of structures and contrast was preserved for higher reduction factors (R=3 and 4) in all the applications as shown by the image of the trabecular bone architecture of the ankle (Figure 1)**,** porcine knee cartilage (Fig 2) and brain vasculature (Fig 3). Periodogram analysis showed similar energy variation across the frequency bins for all reductions (R=2...4) as shown by the 1D periodogram along the phase-encoding direction (Fig 4) of the full FOV and R=4 dataset in Fig2. This implies similar spatial autocorrelation in full-FOV and parallel images and hence similar spatial resolution. Quantitative analysis of the cartilage images yielded nearly identical values of thickness and volume for all reduction factors (Fig 5).

Discussion: This is the first time that PPI has been applied at 7.0 T for the above applications. The GRAPPA based reconstruction technique introduced in this work provided a robust reconstruction for HR as well as phase sensitive applications. Initial results definitely indicate an upward shift in maximum speedup factor at higher field compared to 3 T. However, our current setup is limited by coil hardware. With the availability of appropriate transmit coils and receiver arrays, imaging at even higher acceleration factors (R>=5) will become possible. For HR applications at 7 T, with the increased signal, PPI may play a significant role in improving spatial resolution in standard acquisition time. For SWI applications at 7 T which require long repetition time (TR) reduction of scan time by PPI could enhance clinical feasibility.

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Reference:

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