Assessment of Parallel Acquisition Techniques mSENSE and GRAPPA in Diffusion Tensor Imaging

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Introduction: Diffusion tensor imaging (DTI) with single shot EPI can result in deleterious image artifacts such as signal dropout, gross geometric distortions, and blurring due to the lengthy echo trains associated with EPI. Measures derived from the diffusion tensor, such as the ubiquitous mean diffusivity (Trace/3 ADC) and fractional anisotropy (FA), can be extremely sensitive to these artifacts. By utilizing the spatial dependency of arrays of RF coils to speed up data acquisition by factors of two to four, parallel acquisition techniques, such as the k-space based GRAPPA [1,2] and image space based mSENSE [3,4], could yield better quality diffusion images and enable accurate quantification of Trace/3 ADC and FA in the brain. Single-shot SENSE EPI with an acceleration factor (R) of 2 was shown to improve spatial resolution and reduce geometric distortions in DTI of brain in normal volunteers [5]. However, there are no quantitative reports comparing the two classes of parallel imaging methods in DTI, particularly with higher acceleration factors and rigid 8-element RF coil arrays. The purpose of this study was to compare quantitative diffusion parameters (Trace/3 ADC and FA) obtained with mSENSE and GRAPPA-based DTI with higher acceleration factors up to four versus conventional DTI.

Methods: Images were obtained from five normals (ages 23-28) on a Siemens 1.5T Sonata scanner with an 8-channel phased-array RF coil (MRI Devices) using conventional DTI (R=1), mSENSE DTI, and GRAPPA DTI (commercial parallel imaging software). Conventional single-shot spin-echo diffusion EPI was used: TR / TE / NEX = 3.2 s / 88 ms / 8, 128 x 128 zero filled to 256 x 256, FOV 22 cm, twenty 3 mm thick contiguous axial slices, 6/8 partial Fourier, bandwidth of 1562 Hz/pixel, echo spacing of 0.79 ms, A/P phase encode direction, scan time 3 min. The diffusion tensor was acquired with diffusion gradients along six non-collinear directions (b=1000 s/mm^2) and one without diffusion weighting (b=0 s/mm^2). DTI data was reacquired for R of 2, 3, and 4 for both GRAPPA and mSENSE (72 reference lines). TR was kept constant at 2.5 s and TE minimized for each value of R, namely 76 ms, 71 ms, and 69 ms for R = 2, 3, and 4, respectively. A 2L Ni-doped water bottle (N=3) was used as an isotropic phantom. FA maps were calculated (MRVision) and ROIs were measured in 6 different regions of brain parenchyma per subject: deep white matter (genu of corpus callosum, splenium of corpus callosum, cerebral peduncles) and cortical gray matter at inferior, middle and superior levels. Paired *t*-tests were used for statistical analysis of Trace/3 ADC and FA obtained from conventional DTI (R=1) versus mSENSE DTI and GRAPPA DTI.

Results and Discussion: The SNR measured on b=0 images for conventional DTI (R=1) was ~ 74 and ~ 93 in deep white matter and cortical gray matter, respectively. FA maps derived from mSENSE R=2, 3 and GRAPPA R=2 were of good quality whereas those calculated from mSENSE R=4 and GRAPPA R=3, 4 images were unacceptable and hence quantitative analysis of these latter three cases are not discussed any further (**Fig. 1**). A qualitative assessment of the FA maps obtained by parallel imaging in the former three cases demonstrated less distortions and blurring, and appeared to improve fiber tract delineation relative to the conventional DTI-derived FA maps, in agreement with an earlier study that used SENSE R=2 [5]. An interesting finding in our study is that the effects of these three parallel imaging methods (mSENSE R=2,3; GRAPPA R=2) on Trace/3 ADC and FA differed markedly between cortical gray matter and deep white matter. These three parallel imaging methods in three cortical gray matter regions differed statistically from R=1 in 8/9 FA measurements, as opposed to 4/9 Trace/3 ADC measurements, whereas parallel imaging and R=1 in three deep white matter regions differed in 3/9 FA measurements and 8/9 Trace/3 ADC measurements. Furthermore, in these significantly different measurements, the percentage change in FA was dramatically more than the Trace/3 ADC for parallel imaging relative to R=1 in cortical gray matter (FA 17-54%, Trace/3 ADC 3.6-6.5%) whereas the opposite trend was observed for deep white matter (FA 4.4-15%, Trace/3 ADC 10-26%). On average, the percentage differences (usually increased) in FA from R=1 was ~4%, ~2%, and ~7% in deep white matter and ~23%, ~50%, and ~32% in cortical gray matter for mSENSE R=2, mSENSE R=3, and GRAPPA R=2, respectively (**Fig. 2**). In summary, DTI with mSENSE (R=2,3) and GRAPPA (R=2) yields adequate diffusion maps although there are systematic differences in the actual Trace/3 ADC and FA values.

References : [1] Sodickson *et al* MRM, 38:591(1997). [2] Griswold *et al* MRM, 47:1202 (2002). [3] Pruessman *et al* MRM, 42:952 (1999). [4] Wang *et al* ISMRM Workshop on Parallel Imaging 89 (2001). [5] Bammer *et al* MRM 48:128 (2002). **Acknowledgements :** AHFMR, CIHR, CFI, ASRA, UHF, Heart&Stroke, CSN

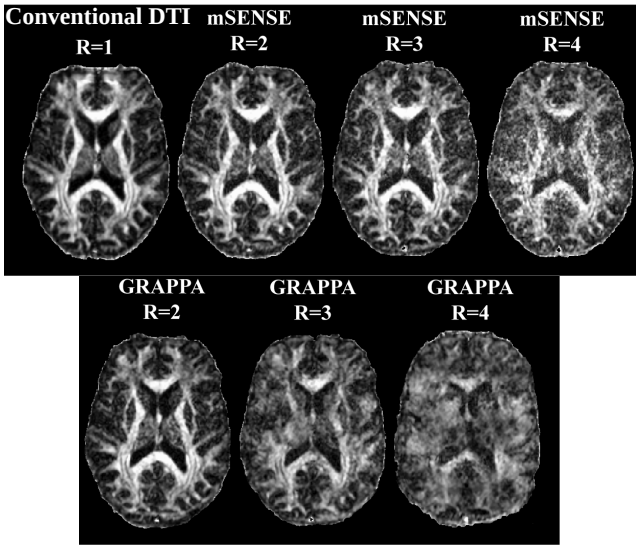

Figure 1: FA maps of an axial slice from one subject.

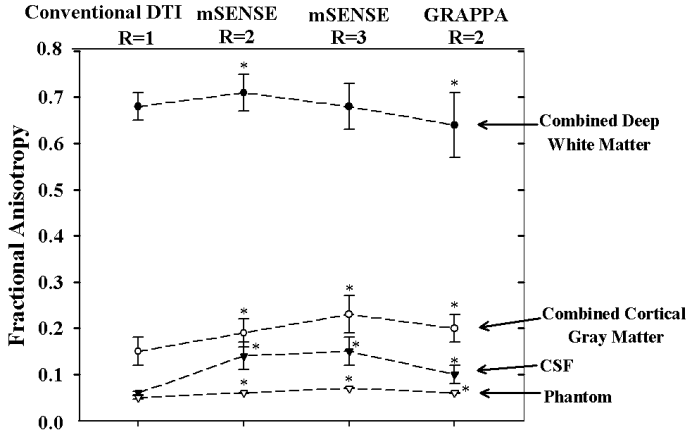

Figure 2: Fractional anisotropy (mean ± SD) for distinct brain regions in five normal volunteers using standard DTI (R=1), mSENSE R=2 DTI, mSENSE R=3 DTI, and GRAPPA R=2 DTI. mSENSE R=4 and GRAPPA R=3, 4 FA values are not shown due to the poor quality of the FA maps. (* $p<0.05$)