High-Resolution Diffusion Imaging of the In Vivo Human Hippocampus

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Introduction: Alterations in microcircuitry of the hippocampus are thought to be important components of neurologic disorders such as Alzheimer's disease and medial temporal epilepsy. To date, the details of medial temporal microcircuitry have eluded diffusion imaging efforts, most likely because typical 2mm isotropic diffusion imaging is inadequate for teasing apart medial temporal anatomy. An important requirement for imaging this microanatomy is high-resolution, high signal-to-noise-ratio (SNR) imaging with minimal distortion to preserve left-right symmetry. While coronal imaging is typically employed in other imaging sequences to separate the intricate substructures of the hippocampus, this poses special challenges for echo-planar imaging (EPI) with regard to distortion. In the coronal plane, distortion will be supero-inferior asymmetric with phase-encoding in the supero-inferior (SI) direction, and left-right asymmetric with phase-encoding in the left-right (LR) direction. Parallel imaging can be employed to reduce distortion. However, with typical 8-channel head coils, parallel imaging can only be employed with phase left-right, and this may not be enough distortion reduction to render the brain symmetric for left-right comparisons and reproducibility. Given these constraints, the goal of this project is to investigate how one can integrate parallel-imaging enhanced EPI to achieve a quantitative balance of resolution, SNR, and distortion to best evaluate hippocampal anatomy and pathology. In particular, we compare a typical 8-channel head coil with a newly available 32-channel head coil, which offers greater flexibility with parallel imaging because of the greater number of coil elements.

Methods: Four subjects provided consent for scanning at 3T in conformance with IRB regulations. Our goal was to compare SNR and distortion with an 8 channel vs. a (2x16) channel coils, manipulating the direction of phase encoding. Two subjects were scanned as follows: EPI with twice-refocused diffusion preparation, TE = 85ms, TR = 3s, b = 1000s/mm^2, 4-10 b = 0 images with the following permutations: 8 channel phase-encoding left-right with a GRAPPA acceleration factor R = 2 (8-CH LR R2), 8-CH SI R1, 32-CH LR R2, 32-CH SI R1, and 32-CH SI R2. Notably, 8-CH SI R2 was not possible because there is only one ring of coils, while the 32-channel coil has two rings, one superior to the other. The number of repetitions was adjusted so that the scan time was identical for each permutation. In addition, one subject was scanned with a very high SNR protocol with phase L-R using the 8 channel coil (EPI twice refocusing, TE = 85ms, TR = 3s, b = 1000 s/mm^2, 128 x 128, 16cm FOV, 3mm thick, 18 slices, 10 T2s, 70 directions, 5 repetitions complex averaged, 40 min scan time), and another subject was scanned with phase S-I using the 32 channel coil with the same parameters except with a FOV = 18cm. Coplanar coronal T2FSE (TR 5, TE 100, NEX 3) images were obtained on this last subject for anatomic visualization. SNR was measured for each voxel across the b = 0 images and averaged for the whole brain using BET from FSL from FMRIB. FA maps were made using in-house software. Persistent angular structure (PAS) maps were computed using Camino from UCL.

Results: Table 1 lists the SNR measurements across coils and parallel imaging configurations. The SNR was slightly higher for the 8CH LR R2 and 32 CH SI R1 combinations, but both of these were lacking in either distortion reduction or left-right symmetry. The 32 channel coil with phase S-I R2 exhibited relatively high SNR compared to the other configurations. Furthermore, it was the only methodology to both incorporate parallel imaging to reduce distortion, and have distortion left-right symmetric in the coronal plane. Figure 1 displays FA maps from the 40-minute acquisition using the 8-channel coil with phase R-L as compared to a 40-minute acquisition using the 32-channel coil with phase S-I. This anterior slice is at the level of the entorhinal cortex (the gateway of input to the hippocampus), where there is an interface between the brain and sphenoid sinus as well as petrous apices. This results in distortion, which is asymmetric for the former coil and symmetric for the latter coil. Respective SNRs were 17 and 21 for the entire imaging volumes. This 23% increase for the 32-channel coil is likely attributable to the differences in in-plane pixel size (1.25 vs. 1.4), which would be expected to contribute to an SNR gain of 25%. Figure 2 shows hippocampal T2FSE images for anatomic reference alongside FA maps from a more posterior slice at the level of the hippocampal head. Intricate hippocampal structure is apparent and further emphasized in the PAS plots in Figure 3. The expected location of the perforant pathway is in red.

Table 1: SNR across coil and parallel imaging methods

	SNR	Distortion	L-R Symmetry
8 CH LR R2	11.2	Not Severe	N
8 CH SI R1	10.5	Severe	Y
32 CH LR R2	10.1	Not Severe	N
32 CH SI R1	10.1	Severe	Y
32 CH SI R2	10.7	Not Severe	Y

Conclusions: Imaging of the medial temporal lobe is desirable in the coronal plane to best discern hippocampal substructures. We found that with our implementation of GRAPPA-accelerated EPI, the best balance of SNR, symmetry, and distortion for diffusion imaging in the coronal plane was achieved by using our 32-channel coil to enable phase S-I R2. Of note, in the coronal plane, none of the permutations would work with R3. A limitation of this configuration is that aliasing of the spinal cord can occur, which could confound interpretation of midline structures, but this should not affect the medial temporal lobes. **Acknowledgement:** GE Healthcare

Figure 1: FA maps for 8-channel L-R phase R2 (top) vs. 32- channel S-I phase R2 (bottom)

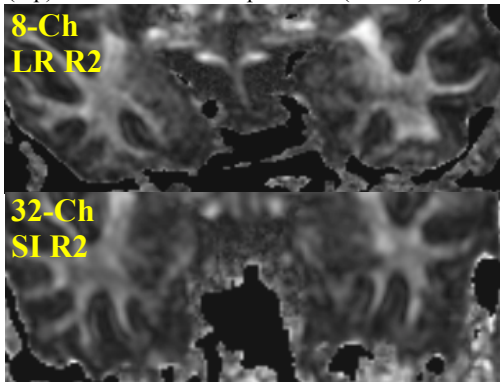

Figure 2: T2 FSE (top) and 32- channel S-I phase R2 FA (bottom)

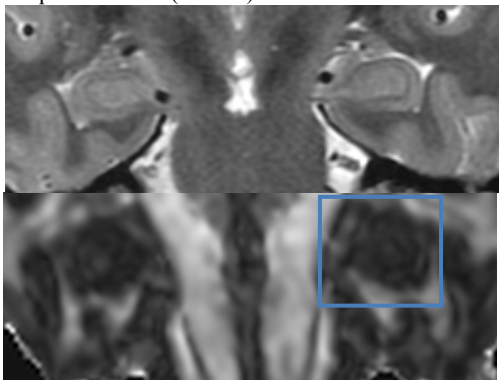

Figure 3: PAS glyphs from blue box inset in figure 2. Expected pathways indicated in red.