High-Resolution Diffusion Tensor Imaging Reveals Sub-Structure whithin Human Hippocampus in vivo

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Introduction

Hippocampal abnormalities are identified commonly in a number of neurological disorders including Alzheimer's disease, temporal lobe epilepsy and developmental amnesia. An early feature of these abnormalities is the loss of the internal architecture of the hippocampus. Diffusion tensor imaging (DTI) provides parameters that are sensitive to tissue damage and degeneration and may therefore have a role to play in monitoring and understanding these conditions. Although this potential has been demonstrated in animal studies ex vivo [1], human DTI studies of the hippocampus [2] have been limited by the low resolution and susceptibility effects associated with single-shot EPI. Diffusion-weighted, multi-shot sequences provide an improved resolution and have reduced susceptibility artifacts, but are highly sensitive to pulsatile brain motion, leading to non-linear, shot-to-shot phase errors. In recent years, a number of multi-shot techniques have been proposed, which reduce this motion sensitivity by incorporating a non-linear phase-correction using data from a 2D navigator [3]. We describe the application of one of these sequences to coronal imaging of the hippocampus. The images obtained reveal structure within the hippocampus on fractional anisotropy (FA) maps that is likely to be related to the alveus, a white matter band located in the superior part of the hippocampus. This demonstrates the potential of high-resolution DTI for mapping hippocampal damage and degeneration in a number of disease states.

Methods

Sequence: Diffusion Tensor Imaging was performed using 2D-navigator-corrected, readout-segmented EPI [4] with an automated re-acquisition scheme to re-acquire data when the motion-induced phase errors were too large for a reliable navigator correction [5]. The re-acquisition procedure makes it possible to acquire robust, artifact-free data without cardiac gating, even in the lower regions of the brain, which are highly susceptible to motion-induced phase errors relating to CSF pulsation. In this study, the algorithm used for re-acquisition resulted in a scan-time increase of less than 20%. The sequence was implemented on a Siemens 1.5T MAGNETOM Avanto system using standard hardware and a modified image reconstruction program to generate images on the scanner at the end of the measurement.

Acquisition: Data were acquired from 7 coronal slices through the hippocampi of two healthy adult volunteers using the following parameters: FOV 173mm x 230mm; matrix 192 x 256; pixel size 0.9mm x 0.9mm; slice thickness 5mm; TR 2500ms; TE 98ms; EPI echo-spacing 320µs; EPI echo-train-length 192; one scan with b=0 and 6 diffusion-weighted scans with different diffusion directions using b=1000s/mm^2. The same measurement was performed 5 times. The scan time for each measurement, including data re-acquisition, was 3min 50secs, giving a total scan time for the 5 measurements of 19.5mins.

Post-Processing: The images were transferred to a separate workstation for further processing. To reduce the effect of motion between measurements, the b=0 images from each measurement were registered to the b=0 image from the first measurement in the series. The same registration transformations were applied to the corresponding diffusion weighted images. The registered images from the 5 measurements were averaged and the data were fit to a diffusion tensor at each pixel, which was used to generate maps of mean diffusivity (MD) and FA. No distortion correction was applied.

Results

As demonstrated by the b=0 image in figure 1, the readout-segmented EPI method provided high resolution images with a low level of susceptibility artitact in the temporal lobes. The diffusion-weighted images showed no evidence of artifacts caused by pulsatile brain motion, as was the case for the MD and FA maps shown in the figure. The FA maps provided sufficient detail to identify internal structure within the hippocampus of both the subjects scanned in this preliminary study.

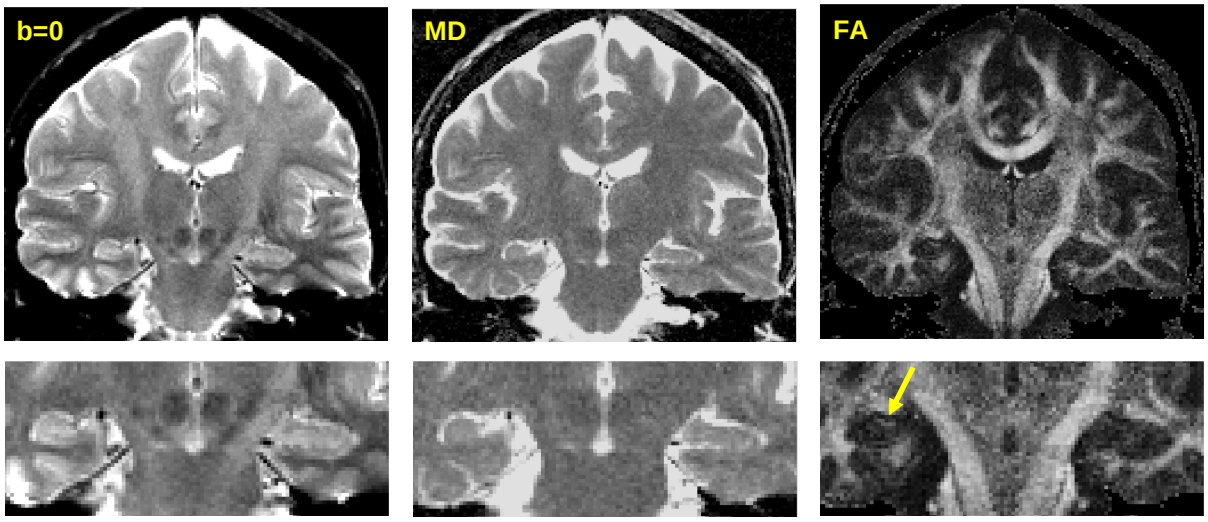

Figure 1: Coronal images through the hippocampus of a healthy volunteer using 2D-navigator-corrected, readout-segmented EPI, showing b=0, mean diffusivity (MD) and fractional anisotropy (FA). The zoomed images in the bottom row provide detail of the hippocampi and the yellow arrow on the FA map identifies a region of elevated FA that is thought to be associated with the alveus of the hippocampus.

Discussion

This study has demonstrated that, using a high-resolution, multi-shot DTI technique, it is possible to visualize white matter sub-structure within the human hippocampus in vivo. These initial findings have important implications for imaging the hippocampus, a procedure that is important in a number of neurological disorders including Alzheimer 's disease, temporal lobe epilepsy and developmental amnesia. The technique may complement other MRI methods such as volumetry and T2-relaxometry, and offers the opportunity to map fractional anisotropy in the hippocampus, a sensitive and established measure of white matter degeneration.

References

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