High resolution imaging of hippocampal internal architecture using HR-MICRA at 3T

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Purpose: The hippocampus is a structure that has been linked to the pathogenesis of epilepsy, Alzheimers disease, schizophrenia, PTSD, and TBI. Most advanced hippocampal imaging analysis has focused on volumetric measurements and surface morphology, but study of the hippocampal *internal* architecture has been largely neglected. We have shown that asymmetries of hippocampal internal architecture are highly specific for predicting the side of seizure onset in temporal lobe epilepsy.[1] The internal structure of the hippocampus is characterized by apposing layers of gray and white matter that create the characteristic spiral appearance of Ammon's horn in coronal section. Specifically the strata radiatum, lacunosum, and moleculare together have a hypointense (dark) appearance on T2w scans, while the pyramidal cell layer (CA1-4) is more hyperintense and is isointense with cortical gray matter. We have previously shown that with conventional high-resolution T2w TSE sequences hippocampal internal architecture (HIA) can be seen clearly in <50% of normal hippocampi.[1] Standard high-resolution sequences with adequate in-plane resolution (<0.5 mm) and SNR to show these structures require a slice thickness (typically 3 mm or greater) that results in blurring of features that are spatially varying through the anterior-posterior dimension of the slice. We propose a method, HR-MICRA (High Resolution Multiple Image Co-Registration and Averaging) for acquiring thin-sliced, high-resolution images that consistently and clearly demonstrate HIA.

Methods: We utilize a variable flip-angle turbo spin echo sequence (VFA-TSE)[2-4] at 3T that we optimized to generate a high-resolution 3D whole-brain image with a relatively short acquisition time, but with poor SNR. The VFA-TSE sequence is capable of turbo factors of 100+ with good gray-white tissue contrast. Our optimized sequence has an in-plane resolution of 0.5 mm (S-I, L-R) and a slice thickness of 0.75 mm (A-P) with a scan time of 6.5 min. The scan is repeated a total of 16 times across two 50-minute sessions. The individual scans are coregistered to correct for movement using FLIRT[5, 6] and averaged to improve SNR. The contrast-to-noise ratio between gray and white matter layers was calculated at 3 positions along Ammon's horn (subiculum, CA1, and CA2) in slices through the body of the hippocampus. These values were compared to those generated with a conventional T2w TSE sequence at 3T (0.25 mm in-plane resolution, 3 mm slice thickness) and a T2* sequence acquired at 7T (0.3 mm in-plane resolution, 0.6 mm slice thickness) in the same individual.

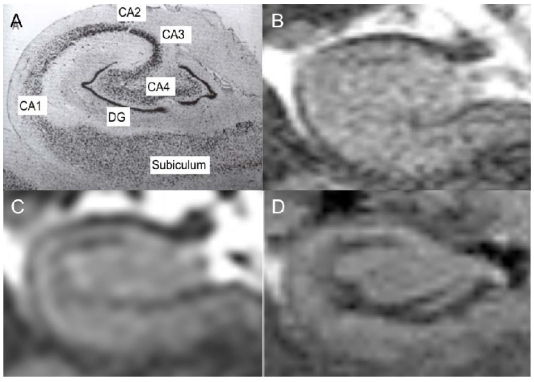

Figure 1. (A) Photomicrograph of body of hippocampus in coronal section. (B-D) Corresponding slices with 3T T2-TSE, 3T HR-MICRA, and 7T T2* respectively.

Results: Figure 1 shows identically oriented slices acquired with the threeThe proposed technique (HR-MICRA) produced a mean (SD) CNR of 6.0 (1.45) which was significantly higher than the conventional 3T TSE sequence at 3.8 (1.1) and only slightly less than the 7T T2* sequence at 7.2 (2.0). ANOVA showed that the means were significantly different between each of the 3 scans. Figure 2 illustrates that regions of loss of HIA clarity (blurring) with 3 mm thick slices result from partial volume averaging in areas shown to be rapidly spatially varying across the corresponding four 0.75 mm thick slices.

Discussion: The laminar internal structure of the hippocampus has a convoluted shape not only in the coronal plane in which it is most commonly visualized, but also along the A-P axis. Clear delineation of these fine features requires not only sub-millimeter in-plane resolution but also sub-millimeter slice thickness. A conventional 2D T2w TSE sequence with 3 mm thick slices takes ~5 minutes to acquire. If the slice thickness was reduced by a factor of 4 to 0.75 mm, then 4 times as many slices would be required to cover the same anatomic volume and the scan would take 20 min to complete. However the reduction in voxel size would result in a 75% drop in SNR. Boosting the SNR back to original levels would require increasing the number of samples averaged by a factor of 16, which would take over 5 hours of scanning, during which the patient would invariably move, causing severe artifacts in the 2D TSE paradigm. The longer echo train length of the VFA-TSE allows for much more efficient use of each TR while maintaining good gray-white contrast, and the 3D nature of the acquisition avoid the issue of gaps or misalignment between adjacent 2D slices, resulting in more accurate coregistration and allowing reconstruction in any plane of section.

Conclusion: the HR-MICRA technique using a VFA-TSE sequence at 3T demonstrates hippocampal internal architecture with greater contrast than a conventional T2w TSE sequence at 3T and with clarity approaching that of 7T T2* images.

References:

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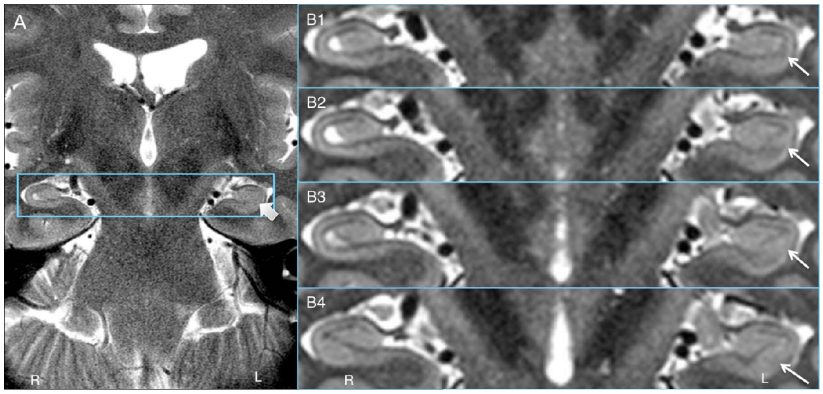

Figure 2. (A) T2 TSE at 3T with 3 mm thick slices. The thick arrow shows an area of loss of HIA clarity. B1-4 show the 3T HR-MICRA 0.75 mm thick slices that correspond to the slice volume of A. Thin arrows show an area of dramatic slice-to-slice variation.