7T spectroscopic imaging of the human amygdala and midbrain

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Introduction: In the brain, the amygdala is believed to function in the processing of emotion and memory, and has been shown to be dysfunctional in many psychological and psychiatric disorders such as post-traumatic stress and bipolar disorders. The MR evaluation of the amygdala can be challenging however, because of its inferior temporal-frontal location lateral to the cavernous sinus, and is particularly problematic for ultra-high field studies. In this study we describe implementation of high degree and order shimming to perform J-refocused spectroscopic imaging using in the region of the midbrain and amygdala at 7T.

Methods: We used a head only Agilent Varian 7T MR system with 1^{st}-3^{rd} order shims and an 8 element transceiver array for all studies. To achieve adequate Bo homogeneity over this region sufficient for spectroscopic imaging, a RRI high (4^{th}) degree shim insert coil was additionally used in conjunction with map based non-iterative shimming methods over the ROI (see Fig 1 for definition). The transceiver array was used with RF shimming to optimize multiple spatially distinct RF distributions to achieve 1kHz B1 transmission over large volumes sufficient for spectroscopic spin echo imaging and outer volume suppression. Spectroscopic localization was achieved with a combination of gradient based slice-selective excitation (10mm thick slices) and RF shimming based outer volume suppression as previously described. All MRSI studies were acquired as a J-refocused double spin echo with TR/TE 1.5s/40ms with rectangular phase encoding, total duration of any study ~80min. Water suppression was achieved through application of three SLR optimized maximal phase 15ms 90° pulses with optimized timings and amplitudes. Phase calibration for the 90° transfer pulse in the J-refocused acquisition was acquired through single scans of water transfer with minimal receiver phase cancellation. Spectral data were processed with a 100Hz convolution difference and 3 to 6Hz exponential to Gaussian conversion. Analysis of the spectra was performed using a least squares minimization of the LCM fit based on GAMMA simulated spectra. At this 40msec echo time, no additional macromolecule baseline was used to analyze the data.

Results: In n=5 volunteers the σBo over the entire ROI with 1^{st}-2^{nd} degree shims was 16.1±4.1; 1^{st}-3^{rd} degree shims 12.4±2.8 and with 1^{st}-4^{th} degree shims 9.5±2.2. Fractionally, 3^{rd} and 4^{th} degree shims improves inhomogeneity by 40.3±5.3% over 1^{st}-2^{nd}; 4^{th} degree improves inhomogeneity by 23.5% over 1^{st}-3^{rd}. Fig. 1 shows field maps showing this improvement. Fig. 2A shows example spectra from a control volunteer, with spectra from the amygdala (including LCM fits), midbrain and cerebral peduncles. All 1^{st}-3^{rd} shim currents were less than 50% of maximum output for each of the shim amplifiers. The aggregate 4^{th} current required was 15.4±5.5 Amps.

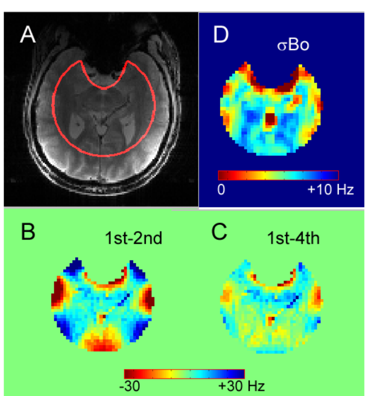

Fig. 1 (far left) Data from the amygdala and midbrain (planum temporale angulation). (A) Scout showing the ROI, (B) Bo field map with 1^{st}-2^{nd} degree shimming, (C) Bo field map after 1^{st}-4^{th} degree shimming, (D) σBo inhomogeneity (linewidth estimate) after 1^{st}-4^{th} degree shimming over the ROI as calculated with a moving boxcar volume, 27 Bo pixels per spectroscopic voxel.

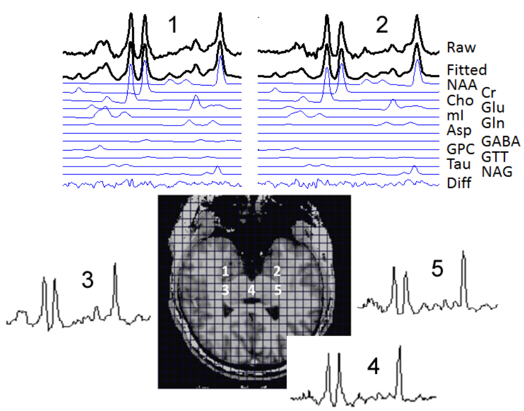

Fig. 2 (close left). Spectroscopic data from an amydala study, showing spectra from indicated loci in the amygdala and midbrain. No baseline correction was used or shown. LCM fits are shown from the amydala with indicated components.

Conclusions: The implementation of 3^{rd} and 4^{th} degree shimming results in more than 40% improvement in σBo over the midbrain-amygdala ROI in comparison to 1^{st}-2^{nd} shimming alone. There was relatively little further improvement with further increase in 4^{th} degree shim currents. As acquired at TE=40ms, the j-refocused sequence enabled LCM analysis with no additional need for baseline correction.