3D GABA Spectroscopic Imaging using MEGA-PEPSI

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Introduction

The ability to measure *in vivo* concentration of gamma aminobutyric acid (GABA), a major inhibitory neurotransmitter, is of high interest to study a variety of nervous system disorders [1] or motor disorders [2]. On clinical 3.0T MRI systems, MEGA-PRESS [3] has gained in popularity over the past years as editing sequence that enables to separate GABA from overlying resonances. However, single voxel MEGA-PRESS measurements are usually acquired from large (~20cc) voxels and have scan times on the order of 8-10 minutes per volume of interest. Recently, 2D GABA spectroscopic imaging techniques, combining the MEGA editing scheme with conventional spectroscopic imaging [4] or high-speed Proton-Echo-Planar-Spectroscopic-Imaging (PEPSI) [5] have been presented to overcome this limitation. 2D MEGA-PEPSI allowed for the acquisition of a 2D dataset within 4-10 min. Here, we show that the fast encoding speed of PEPSI enables extension of GABA mapping to 3 dimensions, enabling the acquisition of several slices with good GABA signal with a spatial resolution of 1.5 x 1.5 x 1.5 cm^3 within 17 minutes of scan time.

Materials and Methods

MEGA-editing pulses were implemented into a 3D slab-selective version of the spin-echo PEPSI pulse sequence described in [6], at alternating frequencies of 1.5 ppm and 7.5 ppm. Frequency alternation of the MEGA pulses and inversion of the excitation pulse for consecutive averages, enables the measurement of a difference spectrum for each PEPSI voxel, only containing resonances from GABA, co-edited macromolecules (the sum of which will be called 'GABA+'), glutamate/glutamine (Glx), NAA and lipids. Using four averages with an elliptical k-space shutter results in a scan time of 18 min to obtain 3D data from 32 x 32 x 8 voxels (TR/TE = 2000 / 68 ms, FOV 480x480x120, slab thickness: 45 mm, voxel size 1.5 x 1.5 x 1.5 cm^3 = 3.4 ml). All measurements were performed on a 3.0 T Tim Trio MRI scanner (Siemens Healthcare) using a 12-channel head coil. In vivo data were acquired in several healthy volunteers. Eight outer volume saturation bands were applied to suppress lipid signals from subcutaneous fat. LCModel fitting was performed using analytically computed basis sets simulating the spectral pattern of GABA, glutamate, glutamine and NAA based on known chemical shifts and *J*-couplings [7].

Results

Careful placing of the outer volume saturation bands allows for the acquisition of GABA-edited spectra in several brain slices including cortical areas. With a slice thickness of 1.5 cm, usually 2-4 slices were located within the slab-selected volume of interest, which also served as shim volume (white box in setup image in Fig 2). The 2-3 slices fully contained within the slab selection were analyzed. Data quality in those slices is high, showing a clear GABA "doublet" at 3 ppm across the full slices. Figure 1 shows representative data from two slices, showing both spectra data quality, and GABA maps obtained from integration as well as from LCModel fitting. Figure 2 shows representative GABA-edited spectra, as displayed directly on the scanner from two 3.7 ml voxels in different slices from a 3D scan encompassing a large brain area.

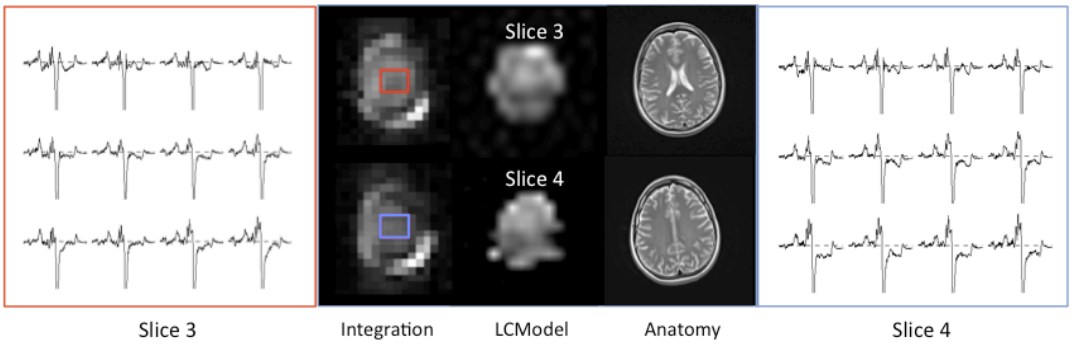

Figure 1: *3D MEGA-PEPSI data acquired over 8 slices, with the slice selective volume covering 2 slices: GABA signal is clearly visible across the full slices in both slices covered by the slice selective volume. GABA maps were generated once by simple integration of the GABA peak at 3ppm, and once by LCModel fitting. Acquisition Parameter: 32x32x8 voxel, voxel size 1.5x1.5x1.5 cm^3, TR/TE = 2000/68 ms, 4 elliptically weighted averages, 17 min scan time.*

Discussion

We have demonstrated the feasibility of fast, high-resolution 3D MEGA-PEPSI for mapping of brain GABA levels across several brain slices with a resolution of below 4ml. Compared to the standard voxel sizes used for single voxel MEGA-PRESS, the resolution is increased by a factor 5, while the SNR of the GABA-edited spectra remains comparable to that of single voxel approaches. The 3D approach has the advantage that slice edge effects, that degrade editing efficiency in 2D MEGA-edited MRSI are avoided, thus increasing overall sensitivity for detecting GABA. A scan time of 17 minutes for the full 3D dataset (8 slices) compares to two single voxel MEGA-PRESS acquisitions, or one 2D MEGA-MRSI acquisition with conventional spectroscopic imaging, but allows more extensive coverage of anatomical structures. Implementing an automatic placement of 16 saturation bands will enable yet larger anatomical coverage, by allowing to cover more slices with the slice-selective/shim volume and more extensive coverage of cortical areas.

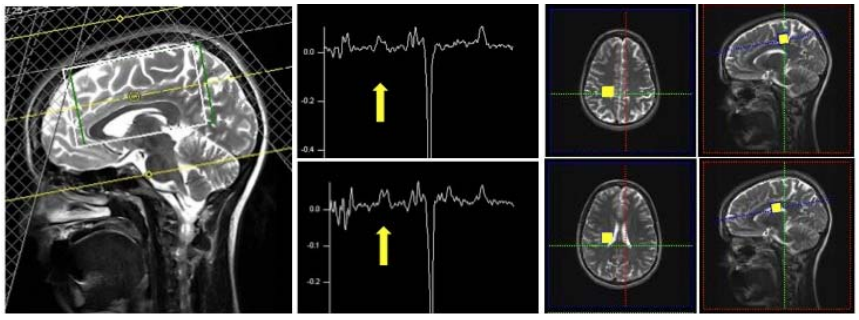

Figure 2: *3D MEGA-PEPSI dataset with slice selective volume covering 4 out of 8 slices. Two representative spectra are shown from different slices, as they are displayed on the scanner.*

References:

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Acknowledgements:

The authors acknowledge financial support from an Indiana CTSI Core Facility grant (U.D.) and from BTRC P41-RR008079 and NCC P30 NS057091 (M.M.).