In Vivo Human Whole Cerebellum MRS under Severe Field Inhomogeneity with iDQC Method

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Introduction: There are clinical cases where acquisition of MRS in a large brain volume is very helpful, such as in whole cerebellum (1) or brain (2) studies. However, this is very difficult with the conventional PRESS single voxel method since it is very sensitive to the local field inhomogeneity (3). Using intermolecular double quantum coherence or iDQC (4), Chen *et al* (5) demonstrated in a controlled study that, when the local magnetic field became inhomogeneous, the 2D iDQC spectra extended along a direction 63.4^o to the F_2 axis, while the line widths measured perpendicular to the extending direction were affected slightly. When the tilted 2D MR spectra were rotated properly and projected onto the F_2 axis, high resolution 1D spectra could be generated. In this study, we extend the method into a localized 2D iDQC MRS sequence and applied it for the whole cerebellum of human subjects on a 3T scanner. High resolution 1D spectra were generated with accurate quantitative metabolite ratios when the conventional PRESS failed in the whole cerebellum.

Materials and Methods: The 2D iDQC MRS sequence was implemented on a 3T Siemens scanner with a standard CP head coil for all the phantom and volunteer studies. As shown in Fig. 1, a frequency selective β pulse of 90^o was placed between the last two spatial selection RF pulses. Coherence selection gradients with area ratio 1:-2 were generated before and after the β pulse, to select only those spins that experienced iDQC during the evolution period, t_1. Both the duration of the evolution period and the delay to the start of the detection period, t_2, were incremented with a step of $\Delta t_1/2$ in a 2D acquisition. A brain MRS phantom was used for phantom studies. A series of line widths, from 5 to 50 Hz, were set manually by adjusting the shimming. Both the PRESS 1D and the 2D iDQC MRS sequences were applied for the same voxel. For each scan, 64 t_1 steps were acquired with Δt_1 = 4 ms for the 2D iDQC MRS sequence. The 1D PRESS data were processed using the Siemens product software. The 2D iDQC MRS raw data were saved for off-line reconstruction. The tilted 2D iDQC spectra were rotate-projected to generate the 1D spectra. In the human studies, five healthy volunteers were scanned using both the 2D iDQC MRS and the 1D PRESS sequences. A 2^3 cm^3 voxel was repeatedly scanned three times using the PRESS sequence, with1st and 2nd order manual shimming. A 4x4x8 cm^3, covering the whole cerebellum, was selected for the 2D iDQC MRS scan, without manual shimming. In total, 128 t1 steps were applied with Δt_1 = 2ms in about 6.5 minutes. The acquisition was repeated 3 times for each subject. The data were processed the same way as for the phantom.

Results: For the controlled phantom studies (data not shown), the Cre and Cho peaks overlap using PRESS with poor shimming. When the shimming is poor for the iDQC MRS acquisitions, 1D spectra with line widths of about 5 Hz can be generated after the 2D spectra are properly rotate-projected. For the volunteer studies, manual shimming become more and more difficult as the voxel size increased, and no PRESS spectra with identifiable separate peaks can be generated for a voxel >= 4^3 cm^3. On the other hand, the iDQC MRS spectra acquired in a 4x4x8 cm^3 voxel are less sensitive to the local field inhomogeneities. High resolution 1D spectra can be generated, with well resolved NAA, Cre and Cho peaks, as shown in Fig 2. Quantitative ratios of NAA/Cre, Cho/Cre, of the five subjects are measured. As shown in Fig 3, the quantitative results match those acquired using PRESS in 2x2x2cm^3 voxels within one standard deviation.

Discussion and Conclusion: The 2D iDQC MRS spectra acquired from large voxels in human brain can be rotate-projected to generate high resolution 1D spectra despite substantial magnetic field inhomogeneity, while the conventional PRESS method fails. The iDQC MRS sequence can be a very convenient method in human brain studies with acceptable scan times. For highly inhomogeneous regions with very short T2*, signals drop quickly especially for the high t_1 resolution. Our quantitative results are acquired on the three major peaks; other metabolites are not reliably detected currently due to SNR limits.

References: (1) Dichgans *et al*, Neurology 2005; 64:608-613. (2) Falini A *et al*, NeuroImage 26 (2005)1159–1163. (3) Gonen O *et al*, MRI 18 (2000) 1255–1258. (4) Warren WS et al, Science 1993; 262:2005-2009. (5) Chen Z *et al*. JACS 2004; 126: 446-447.

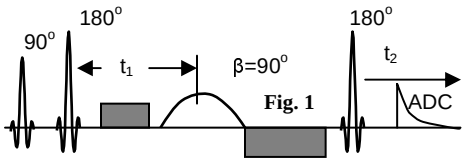

Fig 1. Diagram of the 2D iDQC MRS pulse sequence based on PRESS. The shaded iDQC coherent gradients are applied on z axis.

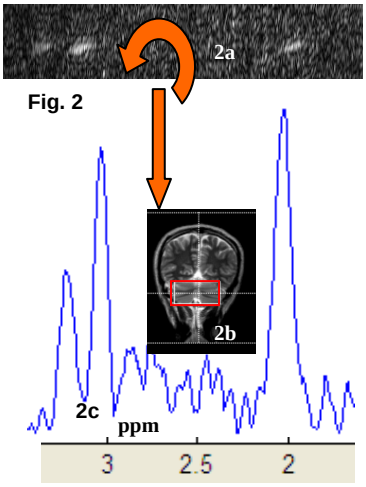

Fig 2. iDQC 2D spectrum (a) acquired in the voxel covering the whole cerebellum (b) and the 1D rotate-projected spectrum (c).

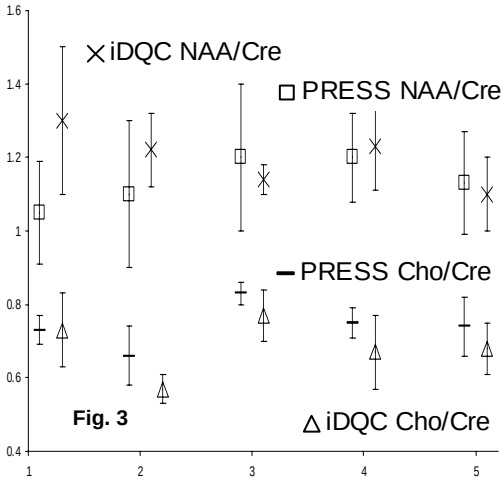

Fig 3. The metabolite ratios calculated in 5 subjects based on the two methods