Prospects of resolution and senstivity enhancement using in vivo iZQC MR spectroscopy

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Introduction MR spectroscopic methods based on intermolecular zero-quantum coherences (iZQC) refocus the dephasing introduced by macroscopic field inhomogeneities [1]. Therefore, spectral quality is less sensitive to susceptibility gradients and, in strongly-structured tissue, resolved spectra can be obtained from larger voxels than with standard single voxel techniques [2]. The spinal cord of the rat is in particular difficult to investigate with standard methods due to its shape and surrounding bone. Especially at high magnetic fields, a satisfying shimming is often not possible and iZQC methods are a promising alternative.

Methods Experiments were performed on a Bruker wide-bore 17.6 T MR system, equipped with a 200 mT/m gradient system and a surface coil. The animals used were healthy female Fisher rats (weight: 130-180g, age: 3-6 months) anesthetised by inhalation with 1.5% Isoflurane. The pulse sequence used was an optimized HOMOGENIZED experiment [1] (Fig. 1) applying a frequency selective 90° pulse after the correlation gradient [3]. The signal is localized by slice selective refocusing (LASER) immediately prior to acquisition [4]. Water signal is suppressed by the frequency-selective second pulse and two selective refocusing modules combined with the localization. In the 2D HOMOGENIZED spectrum metabolite peaks of spin species S are observed at the indirect frequency (ω_{Water} -ω_S), forming a diagonal in the spectrum. 1D projections were calculated by summing a total of eleven digital points around this diagonal along the indirect dimension.

Results Voxels for conventional MR spectroscopy have to be placed avoiding surrounding bone. Due to limitations in shim power at high magnetic fields, extensions along the axis of the spine are limited by deteriorating field homogeneity. With iZQC techniques, significantly larger volumes can be selected, as illustrated in Fig. 2. The iZQC voxel (large square) was only limited by the anatomical borders and B_1-profile of the resonator. A PRESS spectrum from the (2 mm)³ voxel, placed inside a (3 mm)³ voxel that had been shimmed to first order, at the L1 vertebra is shown in Fig. 3. Larger voxels resulted in severe line broadening. The summed projection of the iZQC spectrum from a 4 x 4 x 20 mm³ volume between vertices T12 and L2 is shown in Fig. 4. Peaks of three major metabolites were well-resolved. SNR values (HOMOGENIZED / PRESS) were 15 / 11, 29 / 12, and 9 / 5 for NAA, Cr, and Cho, respectively. 2D HOMOGENIZED required significantly longer measurement times, but higher SNR values show that larger voxel size compensates for lower sensitivity.

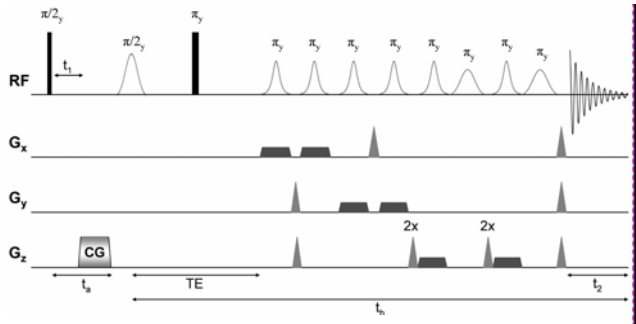

Figure 1: Pulse sequence for localized iZQC spectroscopy.

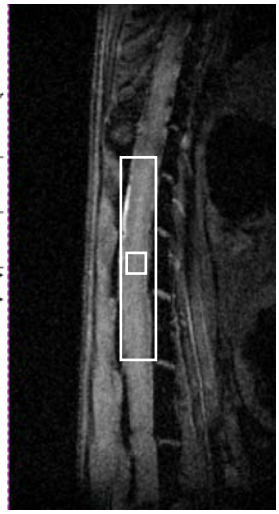

Figure 2: Coronal FLASH image of the rat spinal cord. PRESS spectra were limited to the small voxel indicated, while HOMOGENIZED spectra were obtained from the larger voxel.

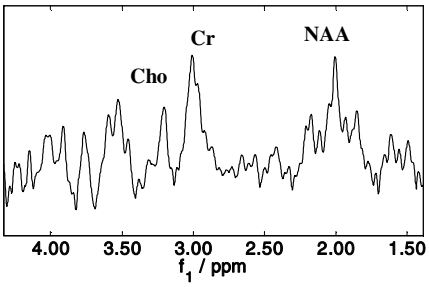

Figure 3: In vivo PRESS spectrum from the region highlighted as a small square in figure 2. TR/TE = 2.0/0.02s, NA = 256, 9 minutes.

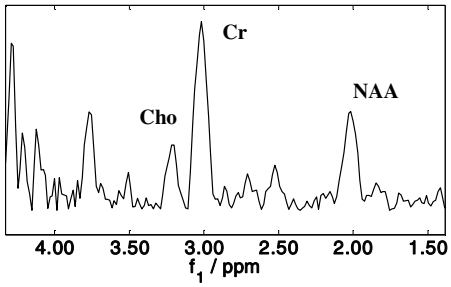

Figure 4: Summed projection of an in vivo HOMOGENIZED spectrum from the region highlighted as a large square in figure 2. TR/TE = 3.0/0.06s, NA = 4, 34 minutes.

Conclusion iZQC techniques provide high-quality in vivo spectra of the spinal cord at 17.6 T. Larger voxel size partly compensates for the inherently low sensitivity of the method. iZQC spectra can be acquired from voxels strongly exceeding shimmed regions or from inhomogeneous tissue, such as e. g. after spinal cord injury.

References

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