Water and Metabolite-Modulated MR Spectroscopy and Spectroscopic Imaging

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Introduction - Proton MR spectroscopy and spectroscopic imaging (MRSI) have traditionally been performed with frequency-selective suppression of the water resonance in order to increase the dynamic range and reduce baseline distortions and vibration-induced sidebands that would otherwise interfere with the detection of low-intensity metabolite resonances. However, detection of the water resonance is important in its own right, be it for absolute quantification, phase correction or B_0 (eddy current) correction. Recently, Dreher and Leibfritz (1) have proposed an elegant, but robust method to detect metabolites in the presence of an unsuppressed water resonance without the complications of water baseline distortions and vibration-induced sidebands. Here we improve their method by eliminating T_1-dependent correction factors and implement the technique for short-echo-time MRS and MRSI.

Methods - All experiments were performed on a 11.74 T Magnex magnet equipped with Magnex gradients (395 mT/m in 120 μs) interfaced to a Bruker console. A LASER based sequence was used for MRS as well as MRSI (TE = 15 ms). The technique of Dreher and Leibfritz was modified to have a single inversion pulse prior to excitation. In experiment 1 the 20 ms adiabatic full passage pulse (R = 60) inverted resonances from -1.6 ppm to 4.4 ppm (upfield metabolites inverted, water not perturbed), while in experiment 2 the same AFP pulse inverted resonances from 5.0 ppm to 11.0 ppm (downfield resonances inverted, water not perturbed). The difference between the two experiments subtracted out the water resonance, including all water-related sidebands, and gave the metabolite spectrum, while the sum resulted in the water spectrum. Each FID was stored separately, Fourier transformed, frequency and phase corrected, after which the difference metabolite spectrum could be calculated. Amplitude corrections were typically much less than 0.25% since differential T_1 relaxation during the inversion pulse was negligible. For comparison, all experiments were repeated with SWAMP water suppression (2) at a correspondingly higher receiver gain.

Results - Fig. 1 shows single-volume (100 uL) MR spectra from rat brain at 11.74 T obtained with (top) and without (bottom) water suppression. In the two base spectrum (with the unsuppressed water resonance), water sidebands are visible at multiple frequencies with amplitudes up to twice the largest metabolite resonance. In the difference spectrum (bottom) all the sidebands are effectively eliminated and there is no difference with the upfield spectrum from a regular water-suppressed acquisition (top). Note however that resonances in the downfield region are greatly enhanced since magnetization transfer between saturated water and exchangeable protons is eliminated. Fig. 2 shows two MR spectra extracted from a single volume in a 20 x 20 MRSI dataset (FOV = 19.2 mm, 1 mm slice) with (top) and without (bottom) water suppression. The spectra are identical to within the noise level. However, the MRSI dataset without water suppression was phase and frequency corrected in an automated manner using the large water resonance.

Conclusions - An improved version of the technique of Dreher and Leibfritz (1) has been presented and implemented for MRS and MRSI. The technique provides high-quality spectra, equal to those obtained with water suppression, but with an improved detection of exchangeable proton resonances. The simultaneously acquired water resonance can be used for absolute quantification, phase and frequency correction and B_0 (eddy current) correction.

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Fig. 1

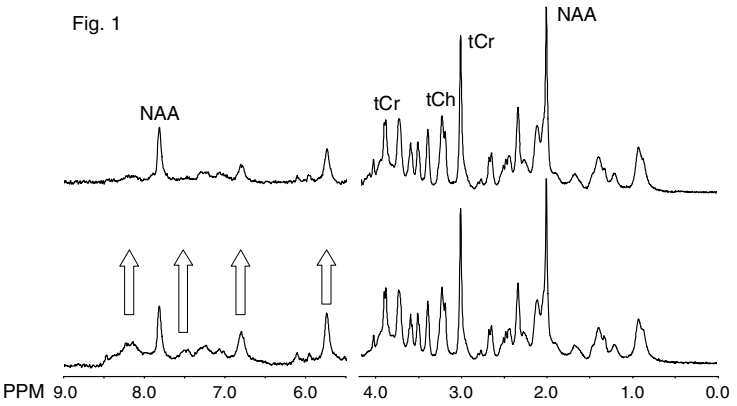

Fig. 2