Introduction

Recently, original ultrafast 2D acquisition schemes have been proposed to collect the 2D NMR data within a single scan [4]. Up to now, these techniques have been applied mainly to organic chemistry [5], analytical chemistry [6] and structural biology [7]. Until now, ultrafast spectroscopic sequences have been implemented on standard spectrometers equipped with one or two magnetic field gradients. In this work, for the first time, we present a 3D localized 2D ultrafast J-resolved spectroscopic sequence.

Method

The proposed ultrafast JPRESS sequence, named ufJPRESS, is based on constant-time phase-modulated spatial encoding (Fig. 1) and was developed on Paravision 5.1 (7T Bruker Biospec). The pulse sequence starts with a water suppression module (VAPOR) combined with a slice saturation module (OVS). These modules are followed by the proposed 3D localized 2D ultrafast J-resolved excitation scheme which is based on the PRESS scheme nested in a modified version of the ultrafast excitation scheme proposed by Pelupessy et al. [8]. The combination of the two 180° chirp pulses, applied during inverted magnetic field gradients (±G), spatially encodes the chemical shift information along the third spatial dimension. The “shifting” gradient pulse (G) is necessary to move the peaks inside the acquisition window. The excitation scheme is followed by a modified EPI detection scheme [9]. The acquisition gradients Ga are separated by non-selective 180° pulses that refocus the effect of internal chemical shifts while the homonuclear J evolution remains unaffected. Two phase cycles Φ₁ and Φ₂ were introduced in order to reduce undesired signals. This scheme, repeated N times, results in a 2N¹T total digitization time. Data reconstruction was processed by a home-made Matlab algorithm. We developed an automatic procedure based on spatial apodization window [10] in order to reduce the asymmetric sinc wiggles inherent to ultrafast MR experiment [11].

A comparative study was carried out to evaluate spectral resolution of conventional and ultrafast 2D J-resolved spectra. 128 transients were acquired using conventional spectroscopy (Echo Times from 20 to 320 ms, NA=1). 128 transients were acquired using ultrafast spectroscopy (G=22 mT/m, 128 detection gradients G=70 mT/m, T=4 ms, G=165 mT/m, T= 600 ms, NA=2). The model sample consisted of a concentrated ethanol solution (10% w/w in water). The voxel size was 8 mm x 8 mm x 8 mm. To evaluate the localization efficiency of the ufJPRESS sequence, tests were performed on a GABA in vitro phantom. This phantom consisted of a 1.5 mL tube containing a GABA solution (10% w/w in water) placed at the center of a 50 mL tube of pure ethanol. The localization test consisted in collecting the ultrafast signal from a voxel (5 mm x 5 mm x 5 mm) placed in the 1.5 mL tube and checking the residual signal of ethanol on the 2D spectrum of GABA. The following parameters were used: G=35 mT/m, 128 detection gradients G=62 mT/m, T=6 ms, G=117 mT/m, T=700 ms, NA=16 and 3 mm OVS bands with a 0.5 mm gap to voxel. All acquisitions were performed using the following parameters: T=30 ms, ζ=15 ms, 9 kHz chirp sweep range, TR=10 s and VAPOR water suppression. The signal (2048 x 128 points) was collected using a quadrature coil (transmit/receive, 32 mm diameter, Rapid Biomed).

Results

As expected, the conventional 2D J-resolved MRS experiment, performed in 21 min, led to a well resolved 2D spectrum with linewidth of less than 2 Hz along the 2 dimensions. The ultrafast 2D J-resolved MRS spectrum, obtained in 20 s, was much better resolved in the conventional F₁ dimension (2.3 Hz linewidth) than in the ultrafast F₂ dimension (17 Hz linewidth). The measured chemical shifts (1.89, 2.28 and 3.01 ppm) and the J-coupling values of GABA obtained for the localization test (Fig. 2) are in good agreement with literature [12]. Very low intensity ethanol peaks (at 1.19 ppm) were reported.

Discussion/Conclusion

These results are in good agreement with the resolution performances of ultrafast NMR experiments which were recently described [13]. The localization test results demonstrate the efficient 3D localization of the ufJPRESS excitation scheme. This paper presents the first 3D localized 2D ultrafast MRS experiment developed on a small animal imaging system. This sequence offers an efficient signal localization allowing the acquisition of a whole 2D J-resolved spectrum in a single scan which is of great interest for investigations on moving organs. Moreover, this sequence acquisition technique could be combined to existing high SNR in vivo spectroscopy applications such as 13C hyperpolarized acquisitions. The time saved using this technique opens new perspectives for in vivo dynamic spectroscopy.

References