Simultaneous Acquisition of Metabolite and Water Signals in 3D Echo Planar Spectroscopic Imaging

T. Shirai[1], S. Hirata[1], and Y. Bito[1]

[1]Central Research Laboratory, Hitachi, Ltd., Kokubunji, Tokyo, Japan

Introduction

Echo planar spectroscopic imaging (EPSI) is one of several approaches to speeding up acquisitions of metabolite spectra from multiple voxels [1, 2]. However, EPSI measurements are very sensitive to temporally and spatially dependent phase and frequency shifts that arise from eddy current caused by oscillating readout gradient of the EPSI sequence. As a result, these phase and frequency shifts can easily distort the metabolite spectrum. Although measuring the water signal to correct the phase and frequency shifts as well as water-suppressed metabolite signal is effective to reduce such spectrum distortion, it increases the scan time, especially for 3D spatial measurement. Therefore, simultaneously acquiring metabolite and water signals is preferable. We have developed a technique to simultaneously acquire both signals in 2D conventional PRESS-CSI sequence [3] and 2D EPSI sequence [4]. In this paper, we describe a technique applied to the 3D EPSI sequence and present the results of phantom measurements utilizing the proposed method.

Method

The technique for simultaneously acquiring metabolite and water signals is implemented in the 3D PRESS-EPSI sequence (Fig. 1). The three CHESS water suppression pulses are applied prior to the PRESS localization. To prevent the contamination of unwanted signal caused by the magnetic field inhomogeneity, the order of slice gradients of excited/refocused planes for the PRESS localization is x (sagittal) - y (coronal) - z (axial) [5]. The technique consists of (1) reversing the polarity of each water signal alternately by three CHESS pulses the amplitude of which is switched in accordance with slice encoding steps, and (2) calculating the water data for the eddy current correction (ECC) from k-space data [3,4]. To prevent the aliasing of the water signal, the slice-encoding gradient with twofold oversampling of the z-axis. The technique can modulate only the water signal in k-space, while the metabolite signal is not affected (Fig. 2(a)). As a result, only the water signal is shifted to the top and bottom of the slice direction of a 3D image reconstructed from the k-space data (Fig. 2(b)). Therefore, the metabolite signal is separable from the water signal by selecting an actual field of view (FOV), as shown in Fig. 2(b) (dashed red square). Next, the method for calculating the water data for the ECC from k-space data is explained. First, the water signal is separated in accordance with its polarity and Fourier transformed into spatial-time domain data. Then linear phase shifts of these data are corrected. By combining these corrected data, the water signal for ECC can be obtained (Fig. 3(a)). The FOV of the water image corresponds to the actual FOV of the metabolite image (dashed red square). The phase distortion of the metabolite signal caused by the eddy currents is corrected by using the calculated water signal (Fig. 3(b)). The calculated water signal can be used for reference data of ECC and signal combination for the multi-channel phased-array coil. This technique may seem to require twofold scan time since it uses twofold oversampling in slice encoding; however, it generally requires the same scan time because the number of signal averaging is usually over two. Furthermore, if we halve the number of signal averaging and set twofold oversampling in slice encoding, the SNR of obtained signal can be maintained without scan time increasing.

The proposed method was applied to a phantom measurement using a round-bottom flask (17 cm dia.) containing a solution of 10 mM N-acetylalanine. All experiments were performed on a 1.5T Echelon (Hitachi, Japan) equipped with an eight-channel phased-array coil. To reduce the chemical shift artifacts, the oscillating readout gradient with twofold oversampling was applied along the y-axis. The main parameters were as follows: TR/TE = 1500/35 ms, image matrix: 12 x 24 x 16, spectral data points: 250 (zero filled to 512 points), spectral bandwidth: 0.5 kHz, FOV: 180 x 360 x 160 mm, volume of interest (VOI) excited/refocused by the RF pulses in the PRESS sequence: 90 x 90 x 60 mm, voxel size: 2.3 cc, image matrix after ECC: 12 x 12 x 8, actual FOV after ECC: 180 x 180 x 80 mm, number of average: 1, and acquisition time: 4.8 min.

Results and Discussion

Fig.4 (a) and (b) show the absolute spectra that added all voxels included in the VOI before and after ECC, respectively. The water signal was sufficiently reduced to clearly reveal the three peaks of N-acetylalanine. Moreover, because ECC corrected the frequency shifts, the half maximum full-width of the N-acetylalanine peak improved. Fig.5 shows the N-acetylalanine images of each slice after ECC. As shown in Fig. 5, since this technique uses twofold oversampling in z-axis, which is the slice encoding direction, it is possible to prevent the aliasing of an unwanted signal caused by the side lobes of the z-axis slice profile. The results demonstrate that this technique is useful for simultaneously acquiring metabolite and water signals.

Conclusion

In this study, we developed a technique for simultaneously acquiring metabolites and water in 3D PRESS-EPSI. The results of phantom experiments showed this technique effectively corrects spectra frequency shifts caused by eddy currents without any increase in scan time, suggesting the usefulness of the proposed method.

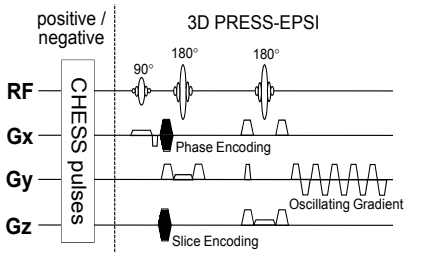

Fig. 1: Sequence diagram of 3D PRESS-EPSI for simultaneous acquisition of metabolite and water.

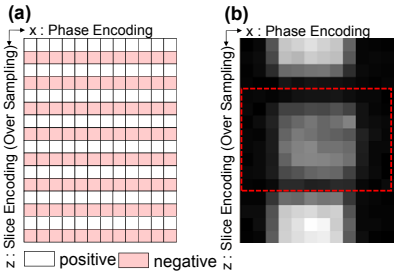

Fig. 2: (a) Measured k-space(x-z plane).
(b) Image obtained by Fourier transformation.

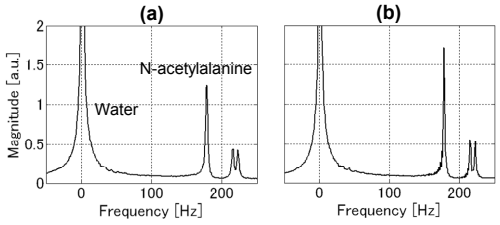

Fig. 4: Absolute spectra that added all voxels included in VOI (a) before and (b) after ECC

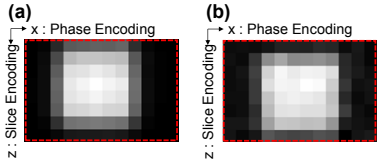

Fig. 3: (a) Calculated water image for ECC.
(b) Corrected metabolite image.

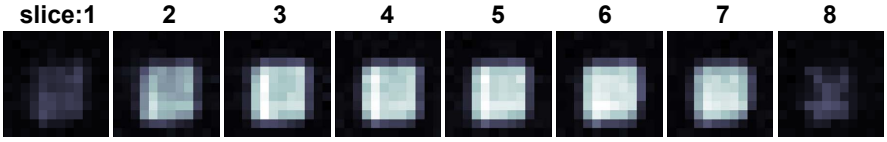

Fig. 5: N-acetylalanine images of each slice after ECC

References

[1] S. Matsui, et al., J. Am. Chem. Soc. 1985; 64: 2817-2818. [2] S. Posse, et al., Magn. Reson. Med. 1995; 33: 34-40. [3] T. Shirai, et al., ISMRM 2008; 16: 1578. [4] T. Shirai, et al., ISMRM 2009; 17: 2380. [5] T. Ernst, et al., Magn. Reson. Med. 1996; 36: 462-468.