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

T. Shirai[1], S. Hirata[1], Y. Yamamoto[2], and Y. Bito[1]

[1]Central Research Laboratory, Hitachi, Ltd., Kokubunji, Tokyo, Japan, [2]Advanced 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, the metabolite spectrum can be easily distorted by these phase and frequency shifts. Although measuring the water signal for correcting the phase and frequency shifts as well as water-suppressed metabolite signal is effective to reduce such distortion of spectrum, it increases the scan time. Therefore, simultaneous acquisition of metabolite and water signals is preferable. We have proposed a technique for simultaneous acquisition of the both signals in conventional PRESS-CSI sequence [2]. In this paper, we propose a technique applied to the EPSI sequence, and the results of healthy volunteer measurements utilizing the proposed method are presented.

Method

The technique for simultaneous acquisition of metabolite and water signals is implemented in the PRESS-EPSI sequence (Fig. 1). The three CHESS water suppression pulses are applied prior to the PRESS localization. The technique consists of (1) reversing the polarity of each water signal alternately by three CHESS pulses, whose amplitude is switched in accordance with phase encoding steps, and (2) calculating the water data for the eddy current correction (ECC) from k-space data [2]. 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 left and right of the image that is reconstructed from the k-space data (Fig. 3(a)). Therefore, the metabolite signal is separable from the water signal by selecting an actual field of view (FOV), as shown in Fig. 3(a) (dashed square). To prevent the aliasing of the water signal, the phase encoding gradient with twofold oversampling of the x-axis. Next, the method for calculating the water data for the ECC from k-space data is explained. First, the water signal is separated according to its polarity, as shown in Fig. 2(b) and (c), 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(b)). The FOV of the water image corresponds to the actual FOV of the metabolite image. The phase distortion of the metabolite signal caused by the eddy currents is corrected by using the calculated water signal (Fig. 3(c)). 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 phase encoding, however, it generally requires the same scan time. Because, the number of signal averaging is usually over two, and if we halve the number of signal averaging and set two fold oversampling in phase encoding, the SNR of obtained signal can be maintained without increase of scan time.

The proposed method was applied to measurement of a healthy volunteer. 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 oversampling was applied along the x-axis. The main parameters were: TR/TE = 1500/35 ms, image matrix: 24 x 24, spectral data points: 250 (zero filled to 512 points), spectral bandwidth: 0.5 kHz, FOV: 240 x 240 mm, volume of interest (VOI) excited/refocused by the RF pulses in the PRESS sequence: 90 x 90 mm, thickness: 15 mm, voxel size: 3.4 cc, image matrix after ECC: 12 x 12, actual FOV after ECC: 120 x 120 mm, number of average: 4, and acquisition time: 2.4 min.

Results and Discussion

The absolute value of spectrum obtained with the water suppression technique is shown in Fig.4 (b). The spectrum was selected from the VOI, as shown in Fig. 4(a) (green square). In Fig. 4 (b), the water signal was sufficiently reduced to clearly reveal the metabolites, N-acetylaspartate (NAA), choline (Cho), creatine (Cr), for example. The absolute value of NAA spectra of the six voxels shown in Fig. 5(a) (blue and red square) with and without ECC are shown in Fig.5 (b) and (c), respectively. In Fig. 5(b), the peak shifts of the spectra were sufficiently corrected. The red square of Fig. 6 (a) shows voxel locations corresponding to the spectra, as shown in (b). The feasibility of performing the EPSI scan in a relatively short scan time, with voxels covering a large volume of interest, is shown in Fig. 6(b).

These results demonstrate that this technique is useful for simultaneous acquisition of metabolite and water signals.

Conclusion

In this study, we proposed a technique for simultaneous acquisition of metabolites and water in EPSI. The results of healthy volunteer experiments showed the effectiveness of this technique in correcting spectrum frequency shifts caused by eddy currents without any increase of scan time, which suggest the usefulness of the proposed method.

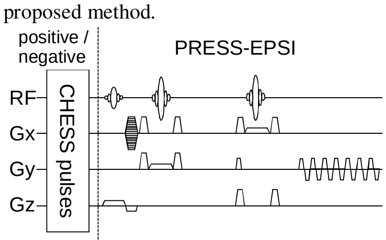

Fig. 1: PRESS-EPSI pulse sequence for simultaneous acquisition of metabolite and water implemented in 1.5T head scanner.

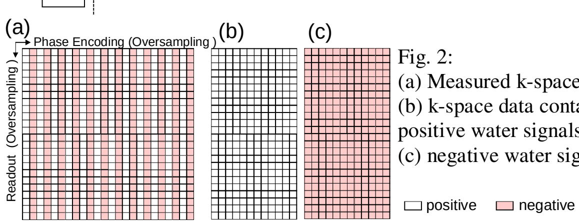

Fig. 2: (a) Measured k-space, (b) k-space data containing positive water signals, (c) negative water signals.

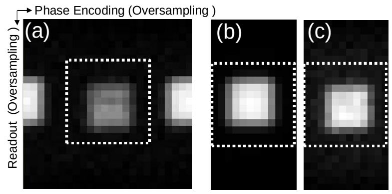

Fig. 3: (a) Image obtained by Fourier transformation of measured k-space data. (b) Combined water image for ECC, (c) corrected metabolite image.

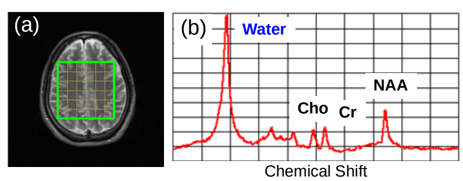

Fig. 4: (a) Green square of image showing VOI location for spectra. (b) Absolute value of water-suppressed spectrum.

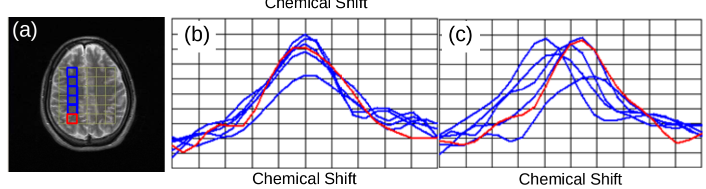

Fig. 5: (a) Blue and red squares of image showing voxel locations for absolute value of NAA spectra (b) with, and (c) without ECC.

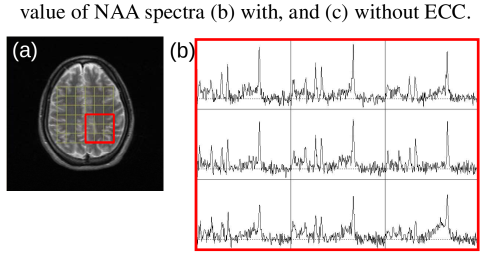

Fig. 6: (a) The red square of image showing voxel locations for the spectra as shown in (b).

References

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