Simultaneous Acquisition of Metabolites and Water Signals Using Multi-Coil Sensitivities

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Introduction

^{1}H chemical shift imaging (CSI) is very useful for the clinical diagnosis of tumors. However, CSI measurements are very sensitive to temporally and spatially dependent phase shifts caused by eddy currents, and the metabolite peaks can be easily distorted by these phase shifts. In order to correct the phase of metabolite signals, the water signal must be measured as along with the water-suppressed metabolites signal [1], which increases the measurement time. Therefore, a simultaneous acquisition of the metabolite and the water signals is necessary. We have developed a new technique for this paper to simultaneously acquire both signals. The technique consists of (i) the measurement shifting of only the water signal on the image, and (ii) a data process that separates the metabolite and water signals using the coil sensitivity difference. Since the superimposed metabolites and water signals received from the multi-coil can be separated using the coil sensitivity difference, both signals can be simultaneously acquired without increasing the scan time. The results from phantom measurements using the proposed technique are presented.

Method

Measurement The pulse sequence for shifting only the water signal on a image is shown in Fig. 1. Prior to the use of a spin-echo (SE) CSI sequence, the polarity of each water signal is alternately reversed by the three CHESS pulses, whose amplitudes are switched in accordance with the phase encoding steps [2]. Only the water signal is modulated in the k-space, while the signal from the metabolites is unaffected (Fig. 2(a)). As a result, only the water signal is shifted to the four corners of the image that is reconstructed by a Fourier transformation (FFT) from the k-space (Fig. 2(b)).

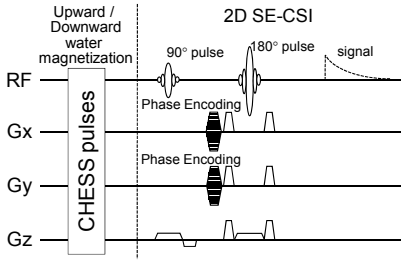

Fig. 1: Sequence diagram of 2D SE-CSI to shift only water signal on image.

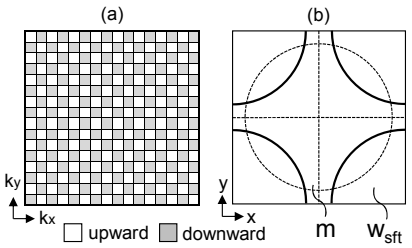

Fig. 2: (a) Measured k-space data, and (b) Image obtained by FFT of the k-space data.

Processing The method of processing for separating the metabolite and water signals using the coil sensitivity difference is explained in this section. The signal received by the k-th coil is given by the following equation:

$$s(k,f,r) = C(k,r)\cdot m(f,r) + C_{sft}(k,r)\cdot w_{sft}(f,r) \qquad (1)$$

where f denotes the spectral sampling point, r denotes the coordinates of the voxel, m denotes the magnitude of the metabolite, w_{sft} denotes the magnitude of the water signal shifted to the four corners of the image, C and C_{sft} denote the sensitivity maps of each coil corresponding to the positions of m and w_{sft}, respectively. The coil sensitivity maps C corresponding to the positions of the metabolite signals can be calculated from the MR images using the method known by the SENSE [3], as shown in Fig. 3(a). On the other hand, as shown in Fig. 3(b), the sensitivity maps C_{sft} corresponding to the position of the water signal can be calculated by shifting the sensitivity maps of the metabolite signals C to the four corners of the maps. As shown in Eq. (1), m and w_{sft} can be separated by using the inversion matrix of the sensitivity matrix, which consists of the C and C_{sft}, if the sensitivity matrix is not ill-conditioned. Then, w_{sft} is corrected to the original position from the four corners of the image for use as the reference data of the eddy current correction (ECC).

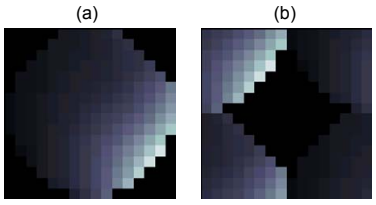

Fig. 3: Sensitivity map (ch. 3) for (a) metabolites and (b) water signal.

Experiments The proposed method was applied to a phantom measurement. The phantom consisted of a round-bottom flask (17 cm dia.) filled with 12.5 mM of N- acetylaspartate (NAA), 10 mM of creatine (Cr), 3.0 mM of choline (Cho), 12.5 mM of glutamate (Glx), 7.5 mM of myo-inositol (mIns), 5.0 mM of lactate, 50 mM of potassium phosphate monobasic, 0.1% of sodium azide, and 0.1% of Gd-DTPA. All the experiments were performed on a 1.5T MR imaging scanner (Echelon Vega, Hitachi Medical Corporation, Japan) equipped with an 8-channel phased-array coil positioned around the phantom on the x-y plane. The main parameters are as follows: TR/TE = 1500/35 ms, 2048 data points, bandwidth: 2 kHz, number of voxels: 16 x 16, FOV: 192 x 192 mm, thickness: 20 mm, and acquisition time: 6.4 min.

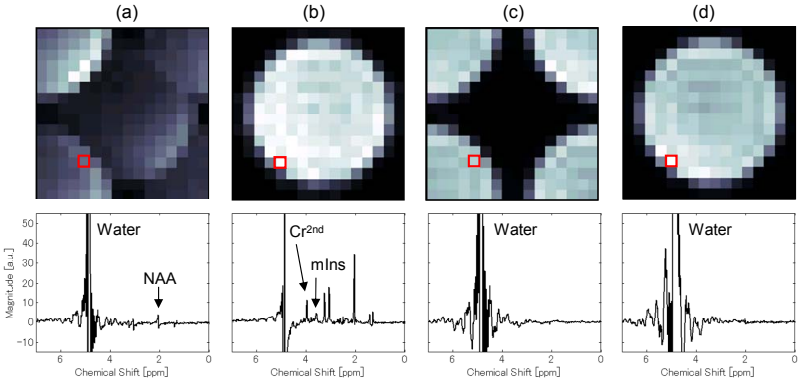

Fig. 4: Upper images are NAA images (a) before separation (ch. 3) and (b) after separation, water images (c) after separation and (d) after position correction from (c). The graphs at the bottom show spectra of the selected voxel (red square).

Results and Discussion

Figures 4(a)-(c) show that the metabolite peaks were sufficiently separated from the water peak. In particular, the Cr 2nd and mIns peaks can be detected. Figure 4(d) shows that the water shifted to the four corners of the image can be corrected from the position in Fig. 4(c). As shown in Fig. 5, the half maximum full-width of the metabolite peaks was sufficiently improved by ECC, because the separated water signal has the correct phase shifts. In the proposed technique, the signals of the metabolites and water can be simultaneously acquired in one scan by separating both of the signals using the coil sensitivity difference. The proposed technique uses the coil sensitivity difference as well as the SENSE-SI technique [4]. However, in the SENSE-SI technique, the subcutaneous fat signal is aliased into the FOV due to undersampling. In contrast, the fat signal is not aliased in the proposed technique, because the undersampling is not used. So, the proposed technique is useful for the simultaneous acquisition of the metabolite and water signals.

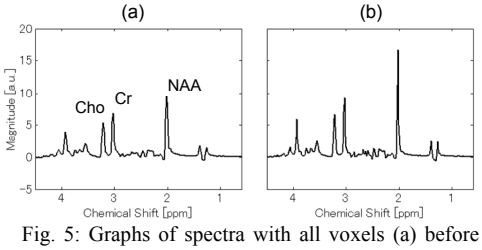

Fig. 5: Graphs of spectra with all voxels (a) before and (b) after eddy current correction.

Conclusion

We developed a new technique in this study for simultaneously acquiring metabolites and water in CSI. The results from phantom experiments showed that this technique effectively corrects the phase shifts in the metabolite peaks caused by eddy currents without increasing the scan time. So the proposed technique is useful for simultaneous acquisition of metabolites and water signals.

References

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[4] U. Dydak et al., MRM, **46**, 713-722, 2001.