Two-echo multiple quantum chemical shift imaging of ascorbic acid (vitamin C) in the human brain *in vivo* at 3 T

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INTRODUCTION

The detection of metabolites with J-coupled spins such as ascorbate (Vitamine C, Asc) in the human brain is particularly challenging due to its low concentration, overlapping resonances (e.g., glutamate, glutamine) and close spectral proximity of the target and the coupled resonances. To date, in vivo measurement of Asc has been reported using a J-difference editing method [1]. J-difference editing method relies on the subtraction of spectra acquired sequentially to remove unwanted overlapping resonances. Thus the method is prone to subtraction error and cannot be expanded to chemical shift imaging. Therefore, the development of a method that does not depend on subtraction of spectra is valuable to study the distribution of Asc in the human brain. In this study, we developed an Asc editing method based on the simultaneous acquisition of multiple quantum (MQ) and single quantum (SQ) signals (STEMS) [2] for reliable *in vivo* measurement of Asc in the human brain at 3 T.

METHODS

The pulse sequence consists of outer volume suppression and water suppression, MQ filtering part for Asc and SQ part for simultaneous measurements of creatine, choline and NAA. Two optimized slice-selective RF pulses (9 lobe sinc, 2.6 ms) were used for the MQ preparation. A doubly frequency selective RF pulse (Gaussian, 60 ms) was inserted between the two MQ preparation pulses to remove unwanted overlapping resonances by selectively refocusing Asc signals at 4.01 and 3.73 ppm. Three-dimensional localization was achieved by two DQ preparation pulses and a pair adiabatic refocusing pulses during the J-refocusing period. The SQ part consists of band-selective excitation (90^{o}_{S}) and refocusing (180^{o}_{S}) pulses followed by three spatially selective refocusing pulses. The frequency band of the excitation and refocusing pulses was set to excite and refocus resonances between 3.3 ppm and 1.0 ppm to suppress water signals but not to disturb T_1 recovery of the Asc signals. Two-dimensional spatial encoding gradients were incorporated at the end of the refocusing period and just prior to data acquisition for chemical shift imaging.

All experiments were performed on a Siemens Allegra 3 T MR system with a custom-built helmet RF coil and interface [3]. The volume of interest for single voxel measurement was positioned in the fronto-parietal region of the brain. For CSI, an axial slab with 3 cm thickness was placed just superior to the ventricle covering fronto-parietal regions of the brain. Sequence parameters were TR / TE = 2000 / 138 ms, voxel size 4x4x3 cm^3 and NT = 512 for single voxel measurements. Parameters for CSI were TR / TE = 2000 / 138 ms, FOV = 20 cm, matrix size = 8 x 8, slice thickness = 3 cm and NT = 10.

RESULTS AND DISCUSSION

Figure 2 shows measurements of Asc from the fronto-parietal region of the human brain *in vivo* using the two-echo MQ technique at 3 T [4]. The selective MQ filtering method provided an unequivocal detection of the Asc signal at 3.7 ppm with an excellent removal of all overlapping singlets and J-coupled signals near 3.7 ppm including Glu and Gln (Fig. 2A). The line shape of the Asc signal was consistent with those of the spectrum extracted from a Asc CSI data set (Fig. 2C) and an Asc solution phantom (Fig. 2D).

Simultaneously measured SQ signals showed clear resonances of Cr, Cho and NAA, providing internal frequency and concentration references for the Asc signal (Fig. 2B). The relative intensities of Cr, Cho and NAA have been altered due to the frequency selection profile of the semi-selective excitation RF pulse used in the MQ part. In addition, almost complete removal of water signals demonstrates the efficiency of the method combining band-selective excitation and refocusing pulses in the SQ part.

We have demonstrated that measurement of a major antioxidant, Asc, is feasible in the human brain *in vivo* and measurement of Asc regional distribution using selective MQ CSI is readily available at clinical magnetic field strength, 3 T.

REFERENCES

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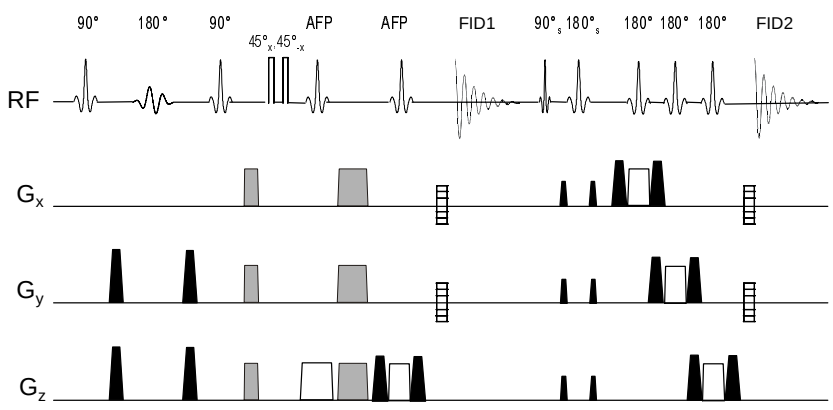

Fig. 1 Pulse sequence diagram of the two echo multiple quantum CSI techniqe for Asc measurement.

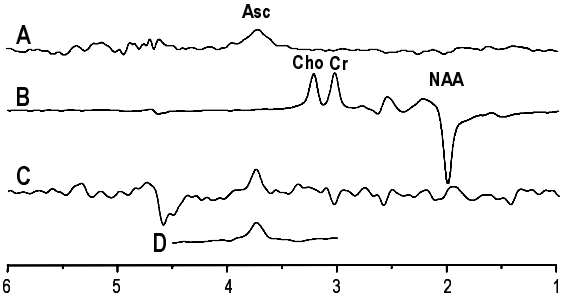

Fig. 2 Ascorbate spectrum in the human brain using the doubly selective MQ filtering method. (A) MQ filtered Asc signal and (B) simultaneously measured SQ signals (Cho, Cr and NAA) of single voxel. (C) Extracted spectrum of Asc CSI and (D) Asc spectrum of a solution phantom (10 mM).