High-Quality Non-Water Suppressed MR Spectra With Correction For Motion Induced Signal Reduction

J-M. Lin[1], S-Y. Tsai[1], C-M. Cheng[2], T-C. Yeh[2], H-S. Liu[1,3], R. V. Mulkern[4], H-W. Chung[1], and N-K. Chen[5]

[1]Department of Electrical Engineering, National Taiwan University, Taipei, Taiwan, [2]Integrated Brain Research Laboratory, Department of Medical Research and Education, Taipei Veterans General Hospital, Taipei, Taiwan, [3]Department of Radiology, Tri-Service General Hospital and National Defense Medical Center, Taipei, Taiwan, [4]Department of Radiology, Children's Hospital and Harvard Medical School, Boston, MA, United States, [5]Department of Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, United States

Introduction

Inevitable motion during sequential single voxel MR spectroscopy scans may significantly degrade the quality of post-averaged spectra through two different mechanisms. First, the motion induced phase variations among different spectral data sets reduce the signal intensities of the averaged data. Second, the susceptibility field gradients and thus the efficiency of MRS water suppression depend on the subject position. This further reduces the quality and consistency of MRS data in the presence of intra-scan motion. It has been shown that the motion induced signal loss in MRS data can be partially restored with "constructive averaging" [1,2,3]. Each spectral data set is phase-corrected based on the frequency shift information estimated from the corresponding residual water signals [1,2] or interleaved reference scan [3], before multiple MRS data sets corresponding to different subject positions or frequency offset conditions are averaged. However, the reliability of frequency offset estimation based on residual water signals may be limited while the quality of residual water signals changes with water suppression (WS) efficiency. In navigator echo based approaches [3], the frequency offset may be calculated from the interleaved non-water suppressed (NWS) signals, but at the expense of prolonged scan time [3]. Furthermore, the MRS data degradation due to inconsistent water suppression in the presence of intra-scan movement is not addressed in those methods.

Here we design a new approach to overcome the limitations of the previously reported MRS "constructive averaging" methods. All MRS data are acquired without water suppression, to eliminate the problems related to inconsistent water suppression efficiency. The frequency offset, corresponding to each subject position or offset conditions, is first measured directly from the water MRS signals. A post-processing procedure is then applied to eliminate water signals, and the remaining metabolite signals are phase-corrected based on the quantified frequency offset information. Constructive averaging is then performed to generate metabolite spectra of high quality and high SNR. The approach enables reliable frequency offset estimation without prolonged scan time.

Methods

MRS data were acquired from single voxels of normal subjects, using a PRESS sequence with a 3T MR scanner. The selected voxel (2x2x2 cm3) was located within the the parietal lobe (white matter), and the PRESS scan parameters included: TE 40ms, TR 2 sec, spectral bandwidth 2 KHz, number of sampling points 2048, and NEX 128. To evaluate the MRS quality with and without the presence of intra-scan subject movement, three data sets were acquired with different conditions: (a) NWS spectra acquired with intra-scan motion, (b) WS spectra acquired with intra-scan motion, and (c) WS spectra acquired without intra-scan motion. The subject was instructed to move the head slightly and randomly during the "motion scan" and to hold the head still during the "stationary scan".

The matrix-pencil (MP) method [4] with rank =1 was used for water component fitting. For the data acquired at "motion scans", the frequency and phase of water signal extracted from NWS spectra were used for motion correction on data set (a) and those of residual water signal extracted from WS spectra were used for motion correction on data set (b). After motion correction the acquired spectra were averaged and MP method was applied to suppress water signal on NWS spectra. WS spectra acquired on data set (c) were averaged without motion correction. The SNR and FWHM of metabolites (including N-Acetyl-Asparatate (NAA), Choline (Cho) and Creatine (Cre)) before and after motion correction were calculated and compared to assess the effectiveness of the correction.

SNR (ratio)	NAA (2.0ppm)	Cho (3.2ppm)	Cre (3.0ppm)	FWHM (NAA)
WS-m-nc	5.7(12%)	4.7(18%)	4.6(17%)	
WS-s	48.6	26.3	27.4	6Hz
WS-m-c	37.0(76%)	20.2(77%)	18.0(66%)	10Hz
NWS-m-c	42.0(86%)	23.1(88%)	25.6(93%)	6Hz

Table 1. Metabolites SNR (percentage to the SNR in (B)) and FWHM of spectra in figure 2. Motion correction algorithm can restore SNR from less than 20% to 65~80% using water signal from WS spectra and to over 85% using water signal from NWS spectrum. Note that spectral line width can be retained using NWS spectrum.

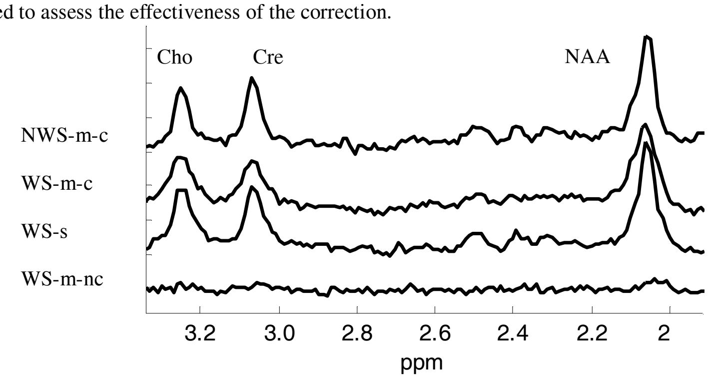

Figure. 2. *In vivo* spectra of WS, subject motion, no phase and frequency correction (WS-m-nc), WS spectrum, subject stationary, no phase or frequency correction (WS-s), WS spectrum, subject motion, correction according to residual water (WS-m-c) and NWS spectrum, subject motion, correction according to water (NWS-m-c).

Result and Discussion

Our results showed that water signal extracted by MP methods can be used to correct severe motion induced SNR degradation, where the metabolite peaks can be retained after motion correction even when no metabolite peak can be identified due to serious motion induced phase cancellation (Figure 2, WS-m-nc). Qualitatively the spectrum corrected by water signal from NWS spectrum (Figure 2, NWS-m-c) is closer to the stationary WS spectrum (Figure 2, WS-s), than that by residue water signal from WS spectrum (Figure 2, WS-m-c). Quantitatively, the SNR and FWHM of metabolites clearly demonstrated the better correction efficiency using water signal from NWS spectrum (Table 1). The better correction efficiency is anticipated to result from the higher SNR of water signal in NWS spectrum than residue water signal and the inconsistent water suppression efficiency during motion in WS spectrum as addressed in the introduction. However, better motion control should be taken to further investigate the efficiency of this method in more details. In conclusion, our preliminary data have demonstrated that our proposed method using internal water signal as reference can successfully restore the motion related phase degradation in NWS PRESS experiment. This concepts of using NWS spectra for metabolite quantification may be particularly beneficial in frontal areas of the brain where water suppression becomes difficult due to susceptibility variations. The motion correction capabilities may also prove useful for spectroscopic studies of the fetal brain[5]

Acknowledgment

We thank NSC 95-2752-B-010-007 for financial support.

References

1.Refaat E. Gabr, et al. Magn Reson Med, 2006. 56: p. 754-760
2.Gunther Helms, et al. Magn Reson Med, 2001. 46: p. 395-400
3.Thorsten Thiel, et al. Magn Reson Med, 2002. 47:p. 1077-1082
4.Yung-Ya Lin, et al. JMR 1997. 128: p. 30-41
5.Rene D. Kok, et al. Magn Reson Med, 2002. 48:611-616