A Comparison of Two Phase Correction Strategies in Multi-Channel MRSI Reconstruction

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Introduction: Magnetic resonance spectroscopic imaging (MRSI) is a noninvasive method for characterizing biologically important metabolic levels. The use of multi-channel receiver coils in MRSI can increase SNR and increase coverage. Realizing optimal SNR from multi-channel acquisitions requires the constructive combination of signal from different receiver coils and thus robust phase correction of spectra from each channel is a critical step in image reconstruction. The automated phase correction algorithms used in our laboratory for processing spectra on a voxel by voxel basis find phase corrections which impose symmetry upon a reference peak in the spectrum and minimize the negative baseline deviations on either side of the peak[1]. For evaluation of multi-channel MRSI data this algorithm has been applied with two different phase correction strategies. The first is to find the optimal phase for voxels from each channel prior to coil combination using metabolite peaks which are greater than 5 standard deviations above the noise in the spectrum and interpolating the values in missing voxels from the surrounding estimates (hereinafter referred as to PC-Voxel). The second is to determine the optimal phase from the sum of the spectra from the central 8 voxels from each channel using water as the reference peak, and then applying this phase from to all voxels in that channel prior to coil combination (hereinafter referred as to PC-Channel). In the latter case voxel by voxel phase corrections based upon metabolite peaks are applied to the spectral array after coil combination. One weakness of PC-Voxel is that it may fail when there are a large number of voxels with metabolite peaks that have low SNR. PC-Channel detects the initial phase correction from the central region of the selected imaging region using the high SNR water peak. The subsequent voxel by voxel phase correction for PC-Channel is applied to the combined data, which has higher signal to noise ratio and a more uniform spatial distribution of metabolite peaks. The purpose of this study is to compare the multi-channel image reconstruction quality using these two strategies at different SNR levels for both phantom and in-vivo data from glioma patients.

Methods: MRSI data for initial analysis of the two methods were acquired from a commercially available MRS phantom. The algorithm was also applied to MRSI datasets obtained from 20 patients with glioma. All imaging studies were performed on a GE Signa 3T scanner (GE Medical Systems, Milwaukee, WI) with 8 channel head coil using PRESS pulse sequence. The parameters for the data acquisitions were TR/TE=1115/144ms, with a FOV of 16×16×16 for flyback echo-planner readout gradients (Tacq=9 min, 1cc effective spatial resolution) and a FOV of 16×16×8 with elliptical k-space sampling for conventional phase encoding (Tacq=17min, 2.43 effective spatial resolution). The phantom data were acquired using flyback echo-planar encoding. The noise level δ in the data from the phantom was measured by averaging the standard deviation (STD) of the 50 points at the end of the raw FID signal in all voxels. Additional random noise was added to the original phantom data to simulate noise levels of 2δ, 4 δ, 6δ, and 8δ. Patient data were divided into two groups. One group contained 10 patients, whose data were acquired using flyback echo-planar encoding, while the other contained 10 patients whose data were acquired using conventional phase encoding. The differences in effective spatial resolution and scan time between the two patient data acquisition schemes were expected to produce differences in the SNR by a factor of 4. Both phase correction strategies were compared at each noise level for the phantom data and between the two groups for the patient data. In-house software was used for all phases of MRSI reconstruction, processing and quantification[2]. The SNR of NAA and Cho in each voxel within PRESS box was measured as the ratio of their peaks to the noise from a region of the spectrum that was devoid of peaks.

Results and Discussion: The data in table 1 shows the results from the two strategies for phantom data at different noise levels. When noise levels were relatively low (e.g., STD= δ, 2δ, 4δ), the two strategies yielded comparable SNR for the combined spectra, with PC-Channel having slightly lower average SNR, probably due to the averaged phase from the central voxels not being entirely representative of differences the spatial distribution of phase between channels. However, as the noise levels increase (e.g., STD= 6δ, 8δ), the SNR of the combined spectra was observed to increase significantly by using PC-Channel. This was because PC-Voxel failed to detect optimal phase for some voxels with low SNR, which led to destructive addition of signal during the combination of the multi-channel data. The data in table 2 show the results of the phasing strategies for two groups of glioma patients. The histograms in figure 1 show the difference in SNR of NAA and Cho between PC-Channel and PC-Voxel on a voxel-by-voxel basis. The data from table 2 and the histograms suggest that PC-Channel provides a more accurate and robust phase correction for the lower SNR echo-planar acquisition, whereas PC-Voxel is adequate for the phase encoding acquisition. Figure 2 shows an example of spectra from one glioma patient acquired with echo-planar acquisition reconstructed using PC-Voxel (Figure 2b) and PC-Channel (Figure2c), respectively. The peak heights of NAA and Cho of some voxels were significantly higher using PC-Channel, compared to those generated by using PC-Voxel in corresponding voxels.

Table 1. Results from SNR comparison of phantom spectra in 256 voxel at different noise levels (STD) reconstructed with 2 different phasing strategies.

	Average SNR of NAA			Average SNR of Cho		
STD	PC-Voxel	PC-Channel	Increase (%)	PC-Voxel	PC-Channel	Increase (%)
δ	100.5	96.0	-4.5	57.7	55.3	-4.2
2δ	33.0	32.0	-3.0	17.8	17.6	-1.1
4δ	20.9	21.2	1.4	11.9	12.6	5.9
6δ	10.6	12.5	17.9	7.2	8.1	12.5
8δ	8.0	11.8	47.5	5.4	7.4	34.3

NOTE. The increase of SNR = (SNR of PC-Channel – SNR of PC-Voxel) /SNR of PC-Voxel .

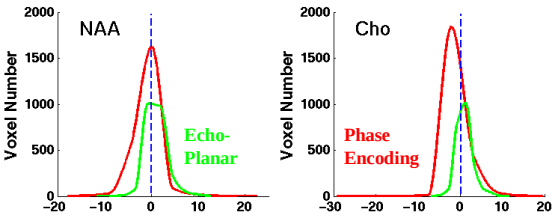
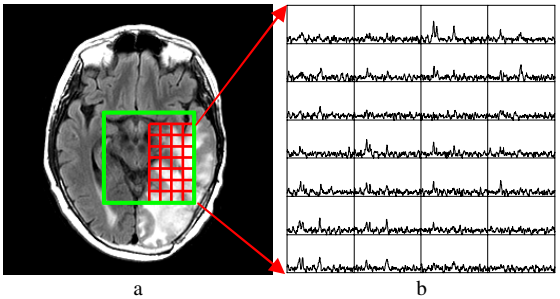


Figure 1. Histograms of the difference in SNR of NAA and Cho between PC-Channel and PC-Voxel on a pixel-by-pixel basis. The differences were measured by subtracting the SNR of PC-Channel from PC-Voxel, and positive change indicates improvement in SNR.



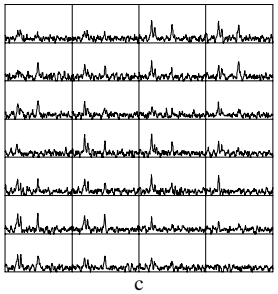


Figure 2. (a) T2 weighted image from a glioma patient superimposed with PRESS box. The grid shows the voxel locations corresponding to the spectra on the right. The patient was scanned using echo planar gradients. (b) Spectra processed using PVoxel. (c) Spectra processed using PChannel. Improvement of SNR of spectra in (c) is obviously seen.

Table 2. Results from SNR comparison between two groups of patient spectra using flyback echo-planar and conventional phase encoding, respectively.

		Average SNR of NAA			Average SNR of Cho		
Acquisition Method	N of patients/voxels	PC-Voxel	PC-Channel	Increase (%)	PC-Voxel	PC-Channel	Increase (%)
Phase encoding	10/2340	38.0	36.9	-2.9	26.6	26.3	-1.1
EP encoding	10/2324	8.6	9.7	12.8	6.8	7.8	14.7

Conclusions: Two phase correction strategies for the reconstruction of multi-channel MRSI were compared in this study. PC-Voxel yielded a slightly improved phase correction for high SNR data but PC-Channel was more robust and accurate for the clinical relevant flyback echo-planar encoding data, which have lower SNR data due to shorter acquisition times and improved spatial resolution[3].

References: 1. Nelson SJ et al., *J Magn Reson Imag* 1989; 84: 95- 109. 2. Nelson SJ. *MRM* 2001;46:228-239. 3. Cunningham CH et al., *MRM* 2005; 54:1286-1289

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