High Resolution Fast Elliptical SENSE MRSI of Gliomas at 7T

E. Ozturk-Isik[1], W. Bian[1], J. M. Lupo[1], D. Xu[1], R. Srinivasan[1], I. Park[1,2], K. Hammond[1,2], D. B. Vigneron[1,2], S. M. Chang[3], and S. J. Nelson[1,2]

[1]Surbeck Laboratory of Advanced Imaging, Department of Radiology, University of California at San Francisco, San Francisco, CA, United States, [2]UCSF/UCB Joint Graduate Group in Bioengineering, University of California at San Francisco and Berkeley, San Francisco, CA, United States, [3]Department of Neurological Surgery, University of California at San Francisco, San Francisco, CA, United States

Introduction: Availability of 7T ultra-high field MR systems has a promise of higher SNR and spectral resolution for MRSI. Higher SNR at 7T can be traded for better spatial resolution to reduce the partial voluming effects for better tumor localization, although this would require more phase encode steps and consecutively a longer scan time with conventional PRESS MRSI localization. In addition, longer repetition times are employed at 7T to avoid the signal saturation due to the longer T1 relaxation times, which already results in a longer scan time. The use of parallel imaging techniques can enable more feasible scan times for a better spatial resolution for patient studies. In this study, we propose high resolution MR spectroscopic imaging of glioma patients at 7T with a scan time of 6 minutes using elliptical SENSE [1] for a 32x32 array with an in plane FOV of 16 cm.

Methods: An MRS phantom containing brain metabolites, a volunteer and three glioma patients were scanned on a 7T MR scanner (GE Healthcare, Waukesha, WI) using a volume transmit coil and an eight channel receiver array (Nova Medical, Wilmington, MA). The imaging protocol included the acquisition of oblique gradient echo (512x512x10, 0.39x0.39x2 mm resolution, NEX=3, TR/TE = 250/17 ms) and proton-density weighted coil sensitivity images (64x64x31, 4.68x4.68x5 mm resolution, TR/TE = 100/1 ms). Elliptical SENSE spectral data acquisition was implemented in a PRESS MRSI sequence with specially designed spectral spatial pulses [2] (32x32, 0.5x0.5x1 cm resolution, 0.25cc voxel size, FOV = 16x16x10 cm, R_x=2, R_y=2, TR/TE = 2000/90 ms, 5000 Hz, 2048 points, 6 min). Data acquisition was restricted to even k-space points that fall into a circular k-space region with less than a distance of 2 to the k-space origin. One VSS outer volume suppression band was placed to the superior part of the slice to minimize the lipid contamination in the spectra. High order shimming was applied to reduce the field inhomogeneity [3]. Data reconstruction for elliptical SENSE spectra was implemented using Matlab 7.0 (The Mathworks Inc., Natick, MA). Proton density weighted coil sensitivity images were resampled to the spectral resolution. Elliptical SENSE spectra were first placed on a respective rectangular grid, and pre-processed using in-house software [4] to generate aliased spectra. These spectra were unaliased 2 fold in both x and y directions. Tikhonov's simple regularization was utilized to condition the inversion problem (λ =4). The elliptical SENSE spectra were quantified to estimate the peak heights and linewidths using in house software [4]. The signal to noise ratio (SNR) of Cho, Cr and NAA were estimated by normalizing their peak heights with the standard deviation of the spectral noise calculated from the left end of the spectrum. The linewidths are reported in number of points and each spectral point was 2.44 Hz. Geometry factor (g) maps were also computed to estimate the noise amplification.

Results: Figure 1 shows the spectra acquired from the black grid placed on the GRE images of the phantom (left), the volunteer (center) and a glioma patient (right). The Cho, Cr and NAA signal intensities were acceptable and they were quantifiable for all the datasets. Table 1 shows the median and range of the geometry factor and the mean±std of the spectral peak heights (h) and linewidths (lw) for all the datasets. The median geometry factor ranged from 1.2 to 1.7, which was similar to the geometry factor values measured at 3T for ellipsoidal SENSE [1]. The mean SNR values were high due to better shimming for the phantom dataset. The mean SNR ranged from 4.3 to 7.5 for Cho, 4.7 to 10.7 for Cr and 8.4 to 21.8 for NAA for the volunteer and glioma patients. The mean linewidths ranged between 6.8 Hz and 14.6 Hz for Cho, 10.5 Hz and 14.2 Hz for Cr, and 15.9 Hz and 26.6 Hz for NAA for the human subjects.

Figure 1. The GRE images (top) and spectra (bottom) for the phantom (left), volunteer (center) and a glioma patient (right).

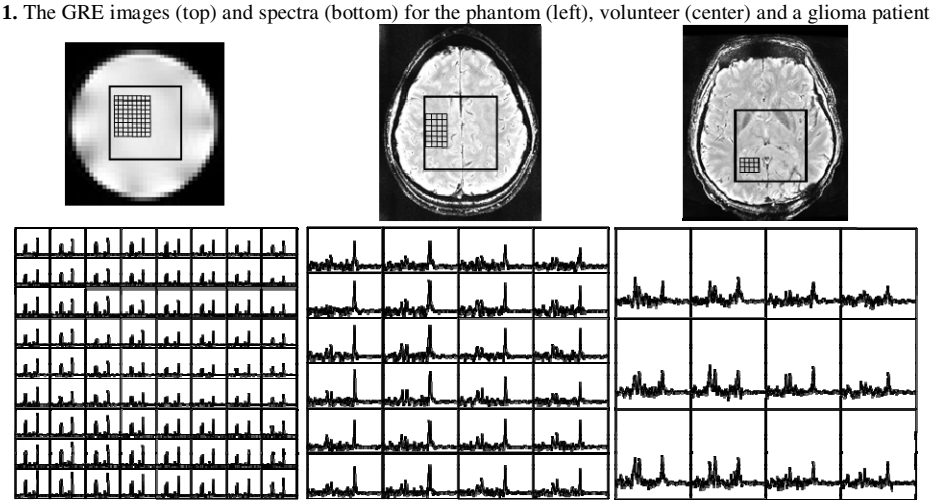

Table 1. The median and range of the geometry factor and the mean±std of the peak heights (h) and linewidths (lw) for Cho, Cr and NAA.

	g-factor median (min-max)	Cho_h	Cr_h	NAA_h	Cho_lw	Cr_lw	NAA_lw
phantom	1.68 (1.11-3.28)	29.8±12.1	34.9±14.6	50.1±21.4	4.3±1.3	4.4±1.1	4.5±1.2
volunteer	1.19 (1.06-1.66)	7.5±3.6	10.7±5.4	21.8±9.7	4.8±2.5	4.9±2.4	6.5±1.5
patient1	1.2 (1.01-1.74)	4.8±2.3	5.2±2.5	9.2±3.7	6±3.8	5.8±3.8	10.9±5.3
patient2	1.26 (1-1.76)	4.3±2.3	4.7±2.8	8.4±5.5	5.1±3.9	5.2±3.8	8.2±4.6
patient3	1.29 (1.05-2.76)	5.8±3.6	10.2±6.4	16.9±10.5	2.8±3.9	4.3±3.7	7.9±5.2

Discussion and Conclusion: The main limitations of the 7T systems are increased susceptibility artifacts, higher B0 and B1 field inhomogeneities, and the need to employ longer repetition times to avoid the signal saturation due to the longer T1 relaxation times. The shimming was the most important factor for getting uniform and high SNR spectra. Due to the variability of shimming over the PRESS box, some areas exhibited lower SNR for all the metabolites. This study demonstrated the application of the elliptical SENSE fast data acquisition technique to acquire higher resolution MRSI data of the brain tumor patients within 6 minutes of scan time at 7T. The smaller voxel sizes would reduce the partial voluming effects to localize tumors more accurately.

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