

Volumetric Chemical Shift Imaging With Low Power Adiabatic Pulses And Fast Spiral Readouts

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Introduction

MR spectroscopic imaging (MRSI) presents several challenges to harvest its full potential in clinical setup. These challenges relate to the main parameters that control the MRSI experiment: 1) B_1 field – conventional RF pulses may have large chemical shift displacement error (CSDE) and non-uniform excitation; 2) phase encoding schemes – traditionally, the spectroscopic data are acquired without readout gradients which in turn require long acquisition times and keep spatial resolution lower than desirable; 3) B_0 field – very good homogeneity (shimming) is required for spectral resolution. The present work addresses the first two categories. A robust combination of optimized adiabatic excitation and fast spiral acquisition was developed for improved volumetric spectroscopic imaging. To date, combination of adiabatic localization and fast acquisition schemes for spectroscopic imaging is not well documented in the literature [1,2].

Methods

Pulses sequences were implemented on whole-body 3T Tim Trio clinical scanners (Siemens, Erlangen, Germany) running IDEA VB17A software. The body coil was used for transmit and the 32-channel head coil for receive. Volume of interest was selected with LASER based on low power adiabatic GOIA-W(16,4) pulses [3]. Spatial encoding was realized with constant density spiral readout gradients [4] for the (k_x, k_y) dimensions, and using conventional phase encoding along k_z . Details of the pulse sequence are shown in Figure 1. The volumetric MRSI obtained with the adiabatic spiral sequence was compared with the “gold standard” conventional phase-encoded volumetric MRSI using the same adiabatic excitation. The agreement between spiral acquisition and phase-encoding was analyzed by Bland-Altman plots [5].

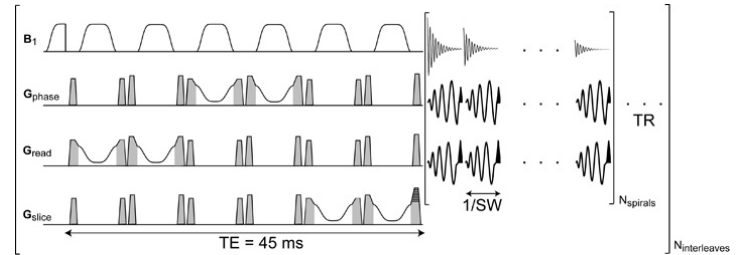


Figure 1. 3D MRSI with LASER-SPIRAL sequence ($N_{\text{spiral}} = 380$, $SW = 1.2$ kHz).

Results

Volumetric MRSI was performed on brain phantoms, volunteers and patients with brain tumors. LASER excitation minimizes chemical shift displacement error, provides uniform flip angles, and reduces the contamination from subcutaneous fat which eliminates the need of outer volume suppression. Spectroscopic imaging of the human brain can be acquired four times faster (2:25 min) using spiral readouts compared to conventional phase encoding (10:07 min) at the same spatial resolution (16x16x8 matrix, 1 ml voxels), or higher spatial resolution (22x22x12 matrix, 0.39 ml voxels) can be obtained twice as fast (4:50 min) than lower resolution (1 ml) phase encoding data at the cost of lower but still clinically adequate SNR. Analysis of the agreement between data obtained with phase encoding and spiral encoding indicates less than 9% difference for the normalized spectral profiles. At higher resolution less partial volume effect is evident in metabolites maps by better delineation of brain structure and pathology.

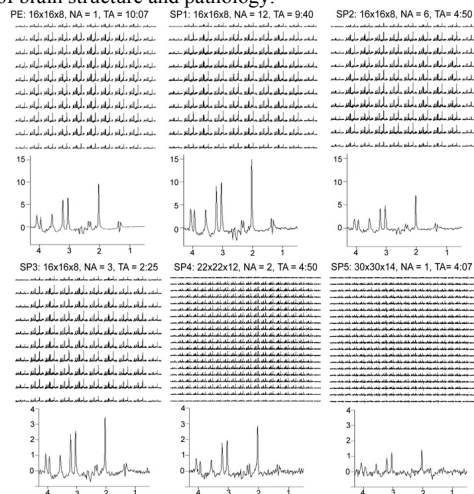


Figure 2. Adiabatic MRSI with one phase-encoded (PE) and five spiral (SP1-5) protocols in a brain phantom. FOV of $160 \times 160 \times 80$ mm³, VOI $100 \times 100 \times 40$ mm³, TE = 45 ms, and TR = 1s was used in all protocols.

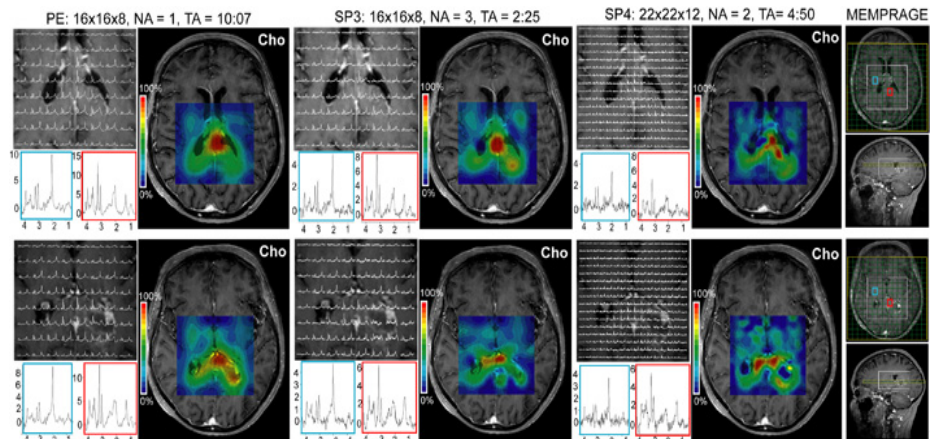


Figure 3. Comparison of adiabatic phase-encoded (PE) and spiral MRSI in a patient with glioblastoma multiforme. Spiral data of higher resolution (60 % smaller voxels) and shorter acquisition times (two faster) are obtained with clinically adequate SNR. Choline maps at higher resolution show better the active and necrotic parts of the tumor. FOV of $160 \times 160 \times 80$ mm³, VOI $80 \times 80 \times 40$ mm³, TE = 45 ms, and TR = 1s was used in all protocols. No outer volume suppression was used.

Conclusions

High resolution adiabatic spiral 3D spectroscopic imaging (0.39 ml voxels) can be performed in a standard clinical MR environment within feasible acquisition times of less than 5 min. Higher resolution (0.15 ml voxels) is demonstrated in phantoms with 4 min of scan time, however for adequate in-vivo SNR averaging for 10 min is necessary. The demonstrated improvement in quality and scan time may enable more routine acquisition of spectroscopic data for patient care. Although the benefit of such sequence is shown for brain tumors, the protocol can be applied to other neurological investigations (metabolic disorders, psychiatric disorders, multiple sclerosis) or to other organs (prostate, liver). Extension to 7T can be realized due to lower SAR of GOIA-W(16,4) pulses compared to standard hyperbolic secant adiabatic pulses.

References: [1] Scheenen T.W. et al, 16th ISMRM Meeting, Toronto, Canada, 2008, #1593; [2] Tachroun M. et al, 17th ISMRM Meeting, Hawaii, USA, 2009, #4312; [3] Andronesi O.C. et al, JMR, 2010, 203:283-293; [4] Adalsteinsson E. et al, MRM, 1998, 39:889-898; [5] Bland J.M. and Altman D.G., Lancet, 1896, 1:307-310.