Implementation of GOIA-Wurst pulse in a SPECIAL localization sequence at 7T

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Introduction

In ^{1}H MR spectroscopy the SPin ECho, full Intensity Acquired Localized (SPECIAL) acquisition sequence combines the advantages of ultra-short echo times (TE) with full sensitivity obtained by Spin Echo (SE) based sequences [1,2]. In particular, J-coupled multiplets and metabolites with short T2 relaxation times benefit from an improved SNR at the short TEs, which are in the order of milliseconds. Increased sensitivity can also be obtained at higher B0 fields, which also provide enhanced spectral resolution. As 7T is currently one of the highest fields available for humans, it makes sense to implement a sequence as SPECIAL on 7T MR systems. However, higher magnetic fields cause RF inhomogeneities and increased chemical shift artefacts in slice selective localization sequences. This can be overcome by applying adiabatic slice selective pulses with large RF bandwidths, though at the cost of an increase in minimal TE.

The aim of this study was to replace the Mao refocusing pulse in SPECIAL with adiabatic pulses, to reduce chemical shift artefact and demands on high B1 amplitudes. To limit the penalty of increased TE, we implemented two GOIA pulses with WURST-16 modulations of the RF field and WURST-4 gradient modulations [3]. These GOIA-WURST(16,4) pulses provide a good excitation uniformity, a very wide BW of 20kHz, while pulse duration (3.56ms) and RF power (0.817kHz) are still comfortably within the limits of most headcoils at ultra-high field strengths. By implementing the two GOIA-W(16,4) pulses, TE increases from 6 to 12.7 ms. Modulation of coupled spin systems is decelerated due to spin locking during the adiabatic passage. To test the SPECIAL-GOIA combination we performed phantom measurements with both Mao and GOIA-W(16,4) refocusing pulses. Furthermore, we obtained *in vivo* brain spectra of a healthy volunteer.

Method

The SPECIAL sequence is a combination of a one-dimensional image-selected in vivo spectroscopy (ISIS) sequence and a slice selective SE sequence (Fig. 1). To obtain full localization three orthogonal slice selections were needed: 1. The 180˚ adiabatic inversion pulse of the ISIS-block was executed in alternate scans, while switching the phase of the receiver at the same time. 2. The use of an asymmetric slice-selective 90° excitation pulse allows ultra-short TE. 3. For 180° refocusing the SPECIAL sequence uses a Mao pulse with a BW of 1.8 kHz, a duration of 3.2 ms and a max RF power 1.7 kHz. In this study we replaced the Mao pulse with two adiabatic GOIA-W(16.4) pulses to achieve 180˚ refocusing. Each GOIA-W(16,4) pulse has a maximum RF power of 0.817 kHz, a BW of 20 kHz and a pulse duration of 3.56 ms. To suppress the water signal VAPOR and an additional Gaussian WS pulse were implemented. Outer volume suppression reduced contaminating lipid signals. All measurements were performed on a 7T Magnetom whole body MR system (Siemens Medical Solutions, Erlangen, Germany) operating at 297.18 MHz for ^{1}H. For measurements in a large spherical brain phantom a custom-built 8-channel Tx/Rx microstrip coil with meanders [4] was used. The phantom contains the following metabolites: 12.5 mM NAA, 3 mM ChoCl, 10 mM Cr, 7.5 mM myo-inositol, 5mM LiLac, 12.5 mM Glu, 50 mM K_2PO_4 and 56 mM NaOH. Both phantom measurements, with Mao and GOIA-W(16,4) refocusing pulses, were executed with the same parameters: VOI = 20×20×20 mm^3, spectral width = 4 kHz, 32 averages, vector size = 2048, TE = 5000ms and a total acquisition time of 2:41 min. Only the TEs differed, 6 ms for Mao and 12.7 ms for GOIA-W(16,4), respectively. The *in vivo* measurements were performed with a 7.0T TX/RX 32ch Head Coil (Nova Medical, Inc., Wilmington, MA, USA). Only signal contributing channels close to the VOI were selected to obtain an optimal signal. The VOI was positioned in grey matter of the parietal lobe of a female volunteer. The measurement parameters were: VOI = 15×15×15 mm^3, spectral width = 4 kHz, 48 averages, vector size = 2048, TE = 4000ms, TE = 6 ms for MAO and TE = 12.7 ms for GOIA-W(16,4). The total acquisition time was 3:13 min.

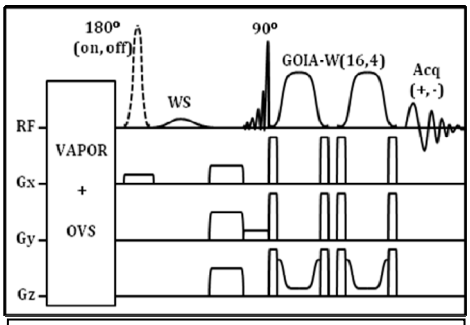

Fig. 1 Sequence diagram of SPECIAL with implemented GOIA-W(16,4) refocusing pulse

Results and Discussion

MR spectra obtained from the phantom with Mao and GOIA-W(16,4) are displayed in Fig 2, in a range of 1.8 – 3.5 ppm. Both spectra show very similar metabolic signal profiles, only very small differences are visible. The glutamate and NAA multiplets at 2.3, 2.5 and 2.7 ppm of the GOIA-spectrum show slightly lower intensities because of longer TE. The *in vivo* ^{1}H MR spectra show similar results (Fig. 3). The NAA multiplets around 2.5 and 2.7 ppm again show a different spectral pattern due to the prolonged J-evolution at the longer TE.

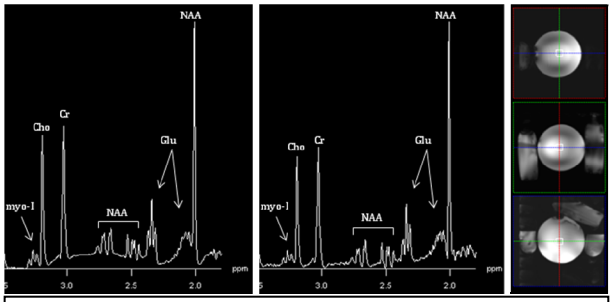

Fig. 2 ^{1}H MR spectra of the brain phantom obtained with Mao (left) and GOIA-W(16,4) (right) refocusing pulse, in the range of 1.8 - 3.5 ppm. At TE 12.7 ms (right) part of the NAA multiplet at 2.5 ppm drops below the baseline.

Conclusion

We demonstrated that the SPECIAL acquisition sequence with the implemented GOIA-W(16,4) pulses shows almost the same spectral patterns as the original sequence with Mao refocusing pulse. Because of the longer TE, some coupled spin systems, such as those of glutamate and NAA, show slight differences in multiplet-lineshape due to J-evolution. Only minor modifications in spectral shape for specific metabolites were observed. This sequence can be used as a proper alternative to obtain short TE MR spectra of the human brain with the benefit of reduced chemical shift artefact and less sensitivity to RF field inhomogeneities, which is particularly important at higher magnetic field.

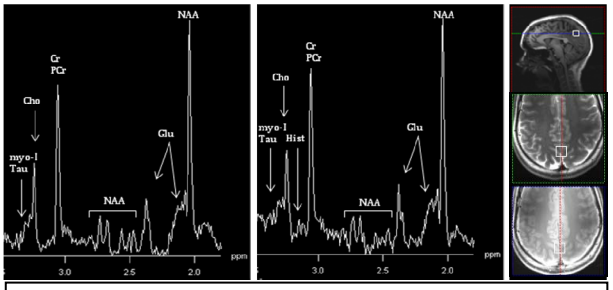

Fig. 3 *in vivo* ^{1}H MR spectra of the human brain obtained with Mao (left) and GOIA-W(16,4) (right) refocusing, in the range of 1.8 - 3.5 ppm.

References

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