High-Quality MR Spectroscopy of the Human Brain with Full Signal Intensity at Echo Times Below 6 ms on a Clinical Platform at 3T and 7T

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Introduction The spin echo full intensity acquired localized (SPECIAL) MR spectroscopy technique was originally devised to unite the advantages of short TEs on the order of ms together with full signal intensity achieved with SE-based scans (1). Recently, its initial implementation on a 3T clinical scanner was reported (2). In this study, the implementation of SPECIAL on a clinical platform was taken to the next level, which combines interleaved water suppression (WS) and outer volume saturation (OVS), optimized sequence timing, and large B_1 fields producing coils in addition to improved shimming. Our aim was to obtain high-quality single voxel spectroscopy (SVS) data of the human brain at TEs below 6 ms on 3T and 7T systems and thus to enable reliable quantitation of metabolites.

Methods Scans were performed on a 3T Trio and a 7T head only system (Siemens Medical Solutions, Erlangen, Germany). On both systems a shielded quadrature transmit/receive surface RF coil consisting of two decoupled single-turn coils was used. At 3T, data were also acquired using a TEM volume coil. First- and second-order shims were adjusted using FASTMAP/FASTESTMAP (3, 4). The VAPOR WS scheme (5) was interleaved with six blocks of OVS to reduce contaminating signals originating from extracranial lipid. Large B_1 peak amplitudes and the use of an asymmetric RF excitation pulse in the SPECIAL method allowed very short TEs (5-7 ms). Results were quantitatively analyzed using LCModel (6).
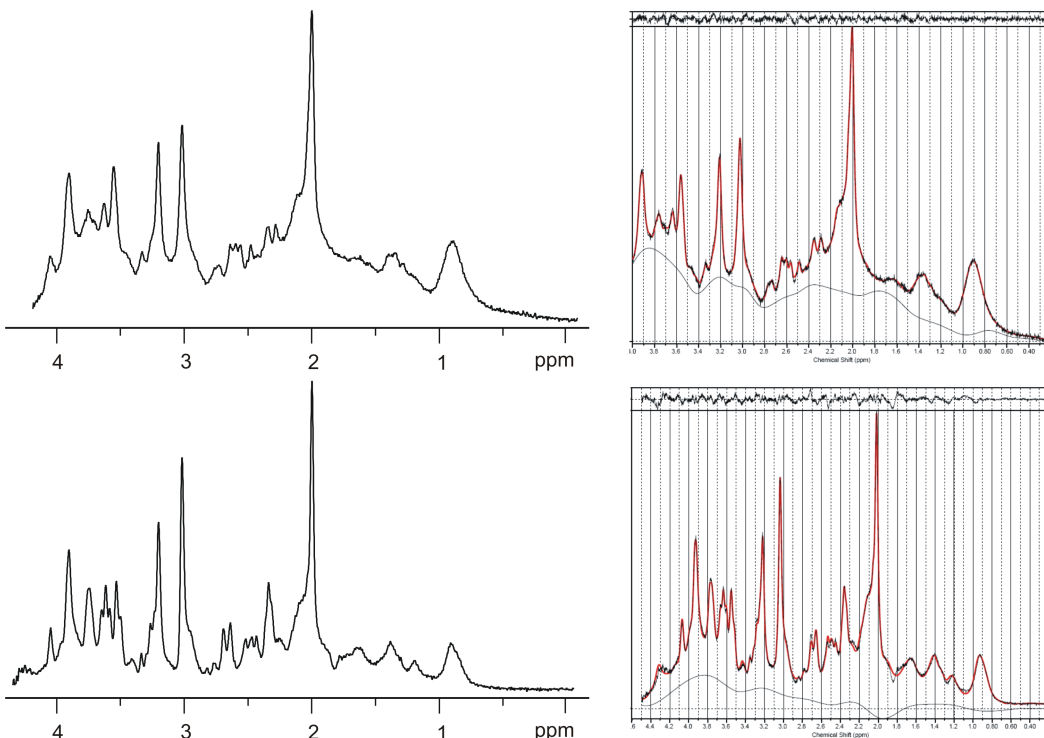

Results ^{1}H spectra from human volunteers acquired at 3T and 7T together with their corresponding fitted curves using LCModel are shown in Fig. 1. Improved localized shimming resulted in water linewidths (LW_{H2O}) ~ 6 Hz in homogeneous gray matter (GM) and white matter (WM) regions at 3T. Similarly, LW_{H2O} ~ 12-14 Hz were obtained at 7T. Excellent WS, specifically for the spectra acquired at 7T, was observed. In all cases, lipid contamination was sufficiently suppressed by the application of OVS. Peaks of Glu (Glx), Ins, and Cr were clearly resolved. A high signal-to-noise ratio (SNR) was obtained by using a surface coil and the SPECIAL acquisition scheme at short TEs. The latter also reduced modulation of J-coupled multiplets. Data of similar quality were acquired at TE=6 ms using a TEM volume coil at 3T (not shown). Comparing the two spectra in Fig. 1, it is noted that the increased spectral resolution at 7T translates into a more defined shape of the spectrum given sufficiently narrow linewidths. At both field strengths, analysis using LCModel yielded excellent fits of the spectra (Fig. 1).

Fig. 1. *Left*: [1]H spectra from human volunteers acquired with an optimized SPECIAL acquisition scheme using a quadrature surface coil. *Upper Left*: 3T, VOI=20x20x20 mm³ in parietal WM, TR/TE=2000/6, BW=2kHz, 256 scans; *Lower Left*: 7T, VOI=30x15x30 mm³ in occipital GM, TR/TE=4000/5.7, BW=4kHz, 64 scans. Data processing consisted of zero-filling up to 16-k data points, shifted Gaussian weighting of the FID, Fourier transformation, and phase correction. *Right*: Corresponding fitted curves using LCModel. Note the excellent agreement between the data (black line) and the fits (red line) also illustrated by the small fit residuals seen above the fits. The SNR calculated by LCModel was 47 for both, the 3T and 7T spectra.

Discussion SVS data of outstanding quality were obtained at 3T and 7T using an optimized implementation of the SPECIAL spectroscopy technique on a clinical platform. The high SNR of the spectra enabled reliable metabolite quantitation at both field strengths. Moreover, the enhanced sensitivity at the higher B_0 field allowed a reduction in scan time by a factor of two. Using the same RF coil and receiver chain, the SPECIAL sequence provides a twofold increase in sensitivity over the STEAM (7) sequence at the same short echo times. Finally, the possibility to use a volume coil at 3T also facilitates clinical application of the technique.

References and Acknowledgements (1) V. Mlynarik et al., MRM, 56(5), 965-970, 2006; (2) R. Mekle et al., Proc. 15th ISMRM, 1351, 2007; (3) R. Gruetter, MRM, 29(6), 804-811. 1993; (4) R. Gruetter, MRM, 43(2), 319-323. 2000; (5) I. Tkac et al., MRM, 41(4), 649-656, 1999; (6) S.W. Provencher et al., MRM, 30(6), 672-679, 1993; (7) J. Frahm et al., JMR, 72(3), 502-508, 1987.
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