In Vivo MR Spectroscopy of Irregularly Shaped Single Voxel Using 2D-Selective RF Excitations Based on a PROPELLER Trajectory

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Introduction

In conventional single-voxel MR spectroscopy (SVS) based on three cross-sectional, slice-selective RF excitations the measured volume is limited to a cuboidal shape. 2D-selective RF (2DRF) excitations [1] are able to excite arbitrarily shaped profiles in their excitation plane and can be used to adapt the measurement volume to the target region which minimizes partial volume effects. This has been demonstrated in previous ^{1}H-SVS studies with 2DRF excitations based on a radial [2] and blipped-planar trajectory [3]. In this work, 2DRF excitations based on a PROPELLER trajectory [4] are used to define an irregularly shaped region of interest at a spatial high resolution from which short-echo-time single-voxel spectra are acquired in the human brain in vivo.

Methods

The PROPELLER trajectory [4] consists of segments of parallel lines ("blades"), which are rotated about the k-space center (Fig. 1a). In order to achieve echo times comparable to those obtained with conventional localization, half-Fourier sampling, known from slice-selective RF excitations [5], was applied in the blip direction, i.e. each blade was covered with two half-Fourier segments ending with the central k-space line (see Fig. 1b). The non-uniform sampling density of the PROPELLER trajectory was estimated using a Voronoi diagram as suggested by Rasche et al. [6] and considered in the calculation of the RF envelope. The basic pulse sequence for the SVS experiments is shown in Fig. 1b. Non-selective refocusing RF pulses were applied between the k-space lines in order to minimize off-resonance effects like chemical-shift displacement artifacts [2]. The signals acquired with the different segments need to be averaged to obtain the desired excitation profile.

Measurements were performed on a 3T whole-body MR system (Siemens Magnetom Trio) with a twelve-channel head coil. Phantom measurements were obtained from a phantom consisting of a small cylindrical bottle (diameter 37 mm) containing 80 mM aqueous N-acetylaspartate (NAA) solution positioned in the center of a larger bottle filled with 70 mM aqueous creatine (Cr) solution and a spherical oil phantom. In vivo data were acquired in healthy volunteers from which informed consent was obtained prior to the examination.

18 half-Fourier segments (nine blades) covering 5 k-lines each were applied yielding a spatial resolution, i.e. a profile sharpness, of 1×1 mm^2 . The 2DRF pulse length was 31 ms with an echo-time contribution of 1.5 ms. MR spectra were obtained with an echo time of 30 ms, four preparation scans, and a voxel thickness of 10 mm. Water suppression was achieved by three CHESS pulses, and spatial saturation pulses were applied to suppress residual side excitations around the target volume. A repetition time of 6 s and four repetitions for each of the 2DRF segments yielded a total acquisition time of 7.6 minutes for the SVS measurements. 2DRF profiles were acquired using an imaging variant of the sequence with phase- and frequency-encoding gradient pulses.

In the phantom, a ring- and circle-shaped regions-of-interest (ROIs) were defined in the outer and inner bottle, respectively. For the in vivo acquisitions, a target ROI covering parieto-occipital grey matter of a healthy volunteer was defined based on a high-resolution (1x1x1 mm³) T1-weighted 3D acquisition of the volunteer's brain. Thereby, only those pixels were included in the excitation profile for which grey matter was found in at least eight of the ten slices relevant for the 10-mm thick voxel.

Results and Discussion

Figure 2 shows MR images of the used 2DRF profiles and the corresponding spectra. In the two-bottle phantom (Fig. 2a) a ring-shaped profile (Fig.2b) in the outer and a circular profile (Fig. 2c) in the inner bottle were measured. The spectra show a very good discrimination of the different metabolites.

The irregularly shaped grey matter ROI is shown in Fig. 2d. MR images of the corresponding excitation profile in an oil phantom (Fig. 2e) and in the same volunteer (Fig. 2f) show a good reproduction of the desired shape. In the corresponding single-voxel spectrum (Fig. 2g), all major metabolites could be identified reliably using LC Model.

Compared to previous ^{1}H MRS studies involving 2DRF excitations [2,3], the PROPELLER trajectory seems to be benificial. Compared to a segmented blipped-planar trajectory with a single line per segment [3], the SNR efficiency is considerably improved because the central (excitation) k-space line is covered with every segment. Because, unlike for a multi-line radial approach [2], the k-space center is passed only once per segment, the PROPELLER trajectory provides a well-defined echo time which for the used half-Fourier segmentation approach is short and comparable to echo times used with conventional localization.

Thus, PROPELLER-2DRF seem to be a promising tool to minimize partial volume effects in single-voxel MR spectroscopy.

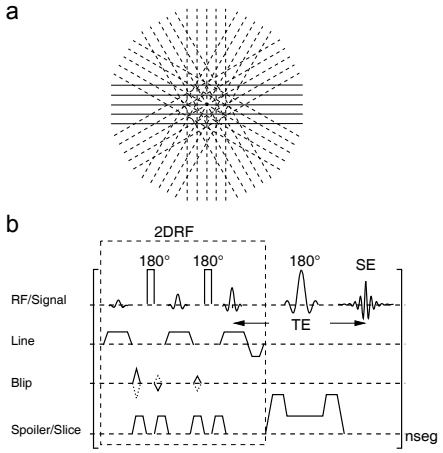

Figure 1: (a) PROPELLER trajectory (six blades with 5 lines each). (b) Basic pulse sequence for spin-echo single-voxel MRS using 2DRF excitations based on a PROPELLER trajectory with half-Fourier segments. The dashed lines represent the blip gradients for the second half-Fourier segment of the blade. The logical axes "Line" and "Blip" rotate with the blade.

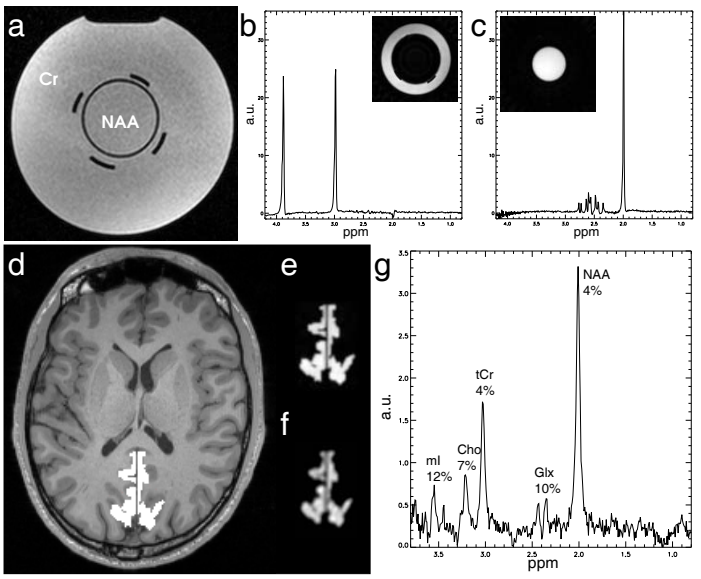

Figure 2: (a) MR image of the two-bottle phantom containing NAA in the inner and creatine in the outer bottle. (b,c) MR images and single-voxel spectra of the ring- and circle-shaped ROIs positioned in the outer and inner bottle, respectively. (d) High-resolution, T1-weighted image of a volunteer with the irregularly shaped ROI in gray matter and (e, f) corresponding excitation profiles acquired in (e) an oil phantom (in-plane resolution 1×1 mm² and (f) the volunteer (2x2 mm². (g) In vivo spectrum of the grey matter ROI acquired in the same volunteer. The values give the lower Cramér-Rao bounds of the metabolites as determined by LC Model.

References

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