IN-VIVO LOCALIZED MAGNETIC RESONANCE SPECTROSCOPY IN SMALL ANIMALS USING PARALLEL SPATIALLY SELECTIVE EXCITATION OF ARBITRARILY SHAPED VOLUMES

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Introduction: Recently, several studies have demonstrated the benefit of segmented parallel excitation (PEX) for localized magnetic resonance spectroscopy (MRS) [1,2]. Using segmented spatially selective pulses provides the possibility of exciting arbitrarily shaped voxels of interest (VOI) with broad spectral bandwidth. These voxels can be adapted to anatomical structures which helps to maximize the signal-to-noise ratio (SNR) while minimizing partial-volume effects. The use of parallel transmission techniques allows reducing the number of segments needed for sufficient spatial resolution of the excited voxel and therefore helps to shorten the experiment duration.
For small-animal MRS it is particularly desirable, due to the small object geometries and the resulting low intrinsic SNR, to collect signal from a maximized volume of interest by adapting the target voxel to anatomical features. In the present study, for the first time, PEX-based localized spectroscopy experiments were performed in a rat brain *in vivo* in order to assess the applicability of PEX for high-field small animal MRS.

Materials and Methods: The experiments in this study were carried out on a BioSpec 9.4 T animal scanner (Bruker BioSpin MRI, Ettlingen, Germany) using an 8-element volume-array for transmission and a rat-head quadrature surface coil for reception. 1H-NMR-spectra were acquired from two different voxels in the brain of a rat, one rectangular voxel lying completely inside an axial section of the brain (voxel area 0.54 cm²) and one complex-shaped voxel following the outline of the brain (voxel area 0.96 cm²) – both with a certain distance to the brain border to avoid partial volume effects (see Fig. 1a). Both voxels had an extension of 4 mm in the head/foot-direction. Spectra from both voxels were acquired using a localized spectroscopy sequence containing a segmented 2D-selective PEX pulse for excitation and a Hermite pulse for selective refocusing in the third dimension. One FID was recorded per excitation segment and the final spectrum was obtained by summation of the spectra corresponding to the different excitation segments. The PEX pulse was designed for a 64x64 matrix in the field of excitation (4.0 cm²) and was based on a radial k-space trajectory with only 20 lines (acceleration factor 3.2, duration of each sub-pulse: 0.440 ms). PEX pulse calculation was performed in the small-tip-angle regime using the method from [3]. To verify the excitation accuracy of the PEX pulse an image of the excited target voxel was acquired using a simple spin-echo sequence with the PEX pulse as the excitation pulse and a Gauss pulse for slice-selective refocusing. For PEX the flip angle (FA) was set to 11°, the maximum possible value due to peak power limitations of the transmit system. A spectral range of 3501 Hz was acquired with a spectral resolution of 0.427 Hz, 13 averages were taken for each of the 20 segments of the PEX sequence. VAPOR water suppression was included while no additional outer-volume suppression (OVS) was performed. As postprocessing 0^{th} order phase correction was applied to the spectra.
For comparison purposes, two spectra from the rectangular voxel were also acquired by using a standard PRESS sequence, one spectrum under similar conditions as the PEX spectra (11° FA, no OVS, 260 averages) and one spectrum under optimized conditions (90° FA, OVS, 260 averages).

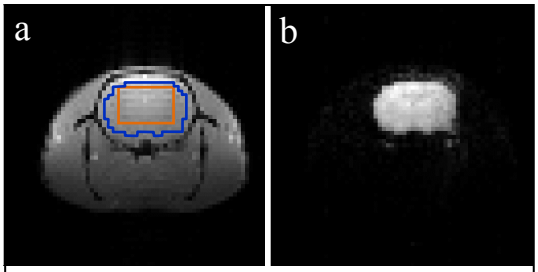

Fig. 1: (a) Axial pilot scan through the rat head displaying the rectangular and the „whole brain“ voxel. (b) Spin echo image of the selectively excited “whole brain” voxel.

Results: The image in Fig. 1b shows that the complex-shaped “whole brain” voxel can be excited with good spatial accuracy using PEX. Only very little spurious excitation can be noticed in the outer volume. In Fig. 2a the “PEX spectra” from the rectangular voxel and from the “whole brain voxel” are compared whereas Fig. 2b displays the two “PRESS spectra” from the rectangular voxel. The PEX and the PRESS spectrum with 11° FA from the rectangular voxel present a similar SNR, and the NAA peak at about 2 ppm as well as the creatinine and choline peaks at about 3 ppm are clearly discernible. However, the spectra display some differences regarding the water line and the fat peak as discussed below.
The comparison of the PEX spectra from the rectangular and the “whole brain” voxel shows that the signal and the SNR in the “whole brain” spectrum is noticeably larger than in the spectrum from the rectangular voxel due to the larger volume of the “whole brain” voxel. The SNR increase of the NAA peak in the “whole brain” spectrum compared to the rectangular voxel spectrum was measured to approximately a factor of 1.73 corresponding very well to the ratio of the voxel sizes of 1.78. Nevertheless, the appearance of the spectra from these two voxels is very similar which indicates that a reasonable shim quality was obtained also for the non-rectangular “whole brain” region and that very likely no signal from structures outside the brain with significantly different spectral composition was collected in the “whole brain” spectrum.

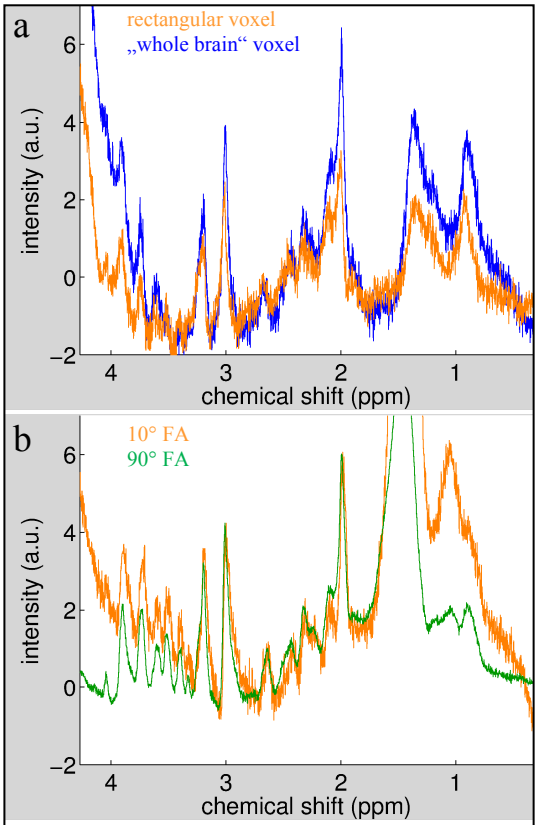

Fig. 2: (a) PEX spectra (11° FA) from the rectangular (orange) and the “whole brain” voxel (blue). (b) PRESS spectra from the rectangular voxel for comparison (orange: 11° FA, no OVS, same intensity unit as in (a); green: 90° FA, OVS, intensity scaled by 0.25 for better visibility).

Discussion and Conclusions: The results of this study demonstrate the *in-vivo* feasibility of localized MR spectroscopy based on segmented PEX pulses in the rat brain. It was shown that for the same excitation angle a similar performance could be obtained compared to using a standard PRESS sequence. In addition, the PEX-based selection seemed to better avoid fat signal collection from the outer volume. One reason for this could be the spatial shift of the PRESS voxel due to the chemical shift of the fat which does not occur for the PEX voxels since the excitation is based on a radial trajectory where the fat off-resonance instead leads to a blurring of the voxel which seems to be more benign in terms of outer volume suppression.
Furthermore, the study clearly shows the SNR benefit when exciting voxels adapted to the object anatomy and exploiting the full volume of the region of interest which is feasible only by using spatially selective excitation pulses.
However, the experiments in this study were still limited by insufficient peak RF power during the transmission of the PEX pulses leading to unrealistically small flip angles and relatively noisy spectra. Fortunately, this problem can likely be overcome by using more elaborate pulse design techniques for the PEX pulses, e.g. including VERSE-like approaches [4]. With this improvement it is expected to achieve a similar or better quality for the spectra than it was obtained by the PRESS sequence with 90° FA. This will be one topic of further investigations. Further experiments will also include spectroscopic acquisition based on 3D-selective excitation pulses which will offer even more degrees of freedom in adapting the spectroscopy voxel to the actual region of interest. Additionally, the acceleration potential provided by PEX in comparison to single-channel SSE will also be better exploited since 3D-SSE-pulses will require a large number of segments which may exceed the number of required averages.

References: [1] Ullmann et al., ISMRM 2011, p. 290 [2] Snyder et al., MRM 2011, published online (DOI: 10.1002/mrm.23018) [3] Grissom et al., MRM 2006, 56:620-629 [4] Conolly et al., JMR 1988, 78:440-458

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