Highly selective excitation method for short TE localized ^{1}H MRS of the frontal lobe at 3 Tesla

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Introduction

Outer voxel contamination strongly deteriorates localized ^{1}H spectra of the frontal lobe, due to frequency shifted water resonances arising from B_0 inhomogeneous regions [1]. Short TE acquisitions are particularly sensitive to this phenomenom because time constraints do not make it possible (i) to apply efficient crusher gradients and (ii) to use long RF pulses required for highly selective localization. Crushing may be improved by optimizing the order of slice selection [1] and by the use of oblique slices [2]. In this context, the development of highly selective short RF pulses would be of major interest to limit outer voxel contamination associated with poorly controlled transition bandwidth and/or unwanted outer ripples. Due to its ability to accurately control the excitation profile, the Shinnar-Leroux (SLR) algorithm is a powerful tool to address this question [3]. The purpose of this study has been to develop a highly selective SLR excitation method to perform localized ^{1}H MRS in the frontal lobe at 3 Tesla. The excitation method relies on the combination of 2 SLR pulses: a conventional 90° pulse (SLR90) presenting very low outer ripples to the expense of the transition bandwidth [3], preceded by outer volume saturation pulses (SLRsat) presenting a very low transition bandwidth [4-5]. Applying both pulses leads to a highly selective square-shaped localization while easily respecting SAR limits at 3 Tesla. The selection profile was acquired *in vivo* and compared to a sinc3 selection profile. Finally, a STEAM spectrum was acquired in the frontal lobe with the proposed excitation method, and was compared to a similar STEAM spectrum localized with sinc3 pulses.

Materials and Methods

NMR system NMR experiments were performed on a whole-body 3 Tesla system (Bruker, Ettlingen, Germany) equipped with a ^{1}H quadrature birdcage probe.

Pulse synthesis Pulse design consists of balancing the conflicting requirements for pulse length (τ), spectral width (SW), inner- and outer-ripples, transition bandwidth (TBW from 5% to 95%), and RF power (maxB1). The SLR algorithm [3] was first used to synthesize a conventional 90° pulse (SLR90) mainly characterized by very low outer-ripples to the expense of the TBW: τ=1.5ms, SW=3500 Hz, TBW=1200Hz, 1% inner-ripples, 0.05% outer-ripples, maxB1=920Hz. Note that maxB1 was kept identical to the maxB1 of a 1.5ms sinc3 pulse. In addition, a saturation pulse (SLRsat) primarily characterized by a very low TBW to the expense of the pulse length was synthesized: τ=8ms, SW=10600 Hz, TBW=100Hz, 0.5% inner-ripples, 1% outer-ripples, maxB1=475Hz. Unlike SLR90, the saturation pulse SLRsat is quadratic phase modulated so that the energy is evenly spread throughout the entire pulse duration [4,5]. This allows the magnitude of B1 to stay relatively constant throughout the pulse duration and thus to minimize the RF peak. Moreover, quadratic phase modulation intrinsically dephases the tilted magnetization, reducing the constraints on spoiler gradients.

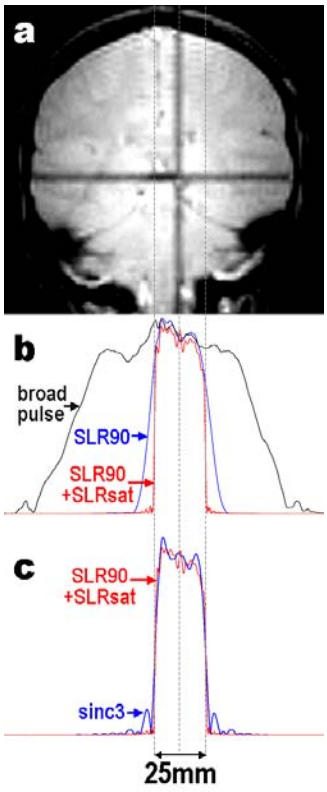

Fig 1. *In vivo* excitation profiles. (a) scout image of the head. (b) non-selective excitation profile (broad pulse), SLR90 profile, and SLR90+SLRsat profile. (c) comparison between the SLR approach (SLR90+SLRsat) and a sinc3 profile.

Combination outer-volume saturation by SLRsat pulses with volume selection by SLR90 theoretically leads to a very sharp localization, simultaneously characterized by a negligible TBW and outer-ripples.

In vivo excitation profiles In order to visualize the excitation profile, a dedicated pulse sequence was written, made of 2 SLRsat pulses (70mm saturation thickness) applied on each side of a 25mm slice selected by SLR90 (perpendicularly to X). A readout gradient was applied along the X direction for profile visualization. Profiles were acquired in one volunteer for the following combinations: non-selective excitation (showing the head profile), SLR90 excitation, SLRsat saturation + SLR90 excitation, sinc3 excitation.

Short echo time spectroscopy of the frontal lobe In order to illustrate the interest of our SLR excitation method for localized spectroscopy, STEAM spectra (TE/TM/TR= 13/300/2500ms, NS=32) were acquired in a 30×30×30mm^3 voxel centered in the frontal lobe. SLRsat pulses were used to suppress outer-voxel magnetization (6 saturation slices of 70mm thickness). Slice selections within the STEAM scheme were achieved using SLR90. A VAPOR water suppression scheme was added to the sequence [6]. STEAM spectra were first acquired using the SLR excitation method. Then STEAM spectra were acquired during the same experiment after turning off SLRsat and replacing SLR90 pulses by sinc3 pulses of the same duration.

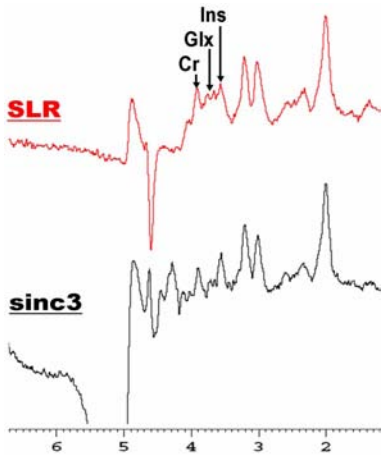

Fig 2. STEAM spectra of the frontal lobe: SLR-localized spectrum (top) and sinc3-localized spectrum of the exact same brain region (bottom).

Results and Discussion

Fig. 1 presents excitation profiles acquired on a human head. The combined use of SLR90 and SLRsat leads to a highly sharp selection (Fig. 1b). As compared with a sinc3 selection (Fig. 1c), the SLR approach reduces the effective transition bandwidth: the TBW/SW ratio is brought from 17% down to 8%. Moreover, outer ripples are considerably decreased (by a factor 5 to 10, depending on the ripple considered). Fig. 2 presents a 13ms echo-time STEAM spectrum acquired in the frontal lobe with the SLR excitation method and a STEAM spectrum localized with sinc3 pulses during the same experiment. The SLR localized spectrum appears free of artefact in the 1-4.5ppm range. A slight water residual can be identified at 4.7ppm. In particular, resonances of creatine (Cr), myo-inositol (Ins), glutamate+glutamine (Glx) can be identified in the 3.5-4ppm range. In contrast, the same voxel localized by sinc3 pulses exhibits severe artefacts in the 3.5-4.5 ppm range, making it impossible to ascribe Cr, Ins and Glx peaks.

Conclusion

This study demonstrates the ability to achieve a short echo-time highly selective excitation respecting SAR limitations at 3 Tesla. The excitation method relies on the optimal combination of 90° SLR pulses with phase quadratic modulated saturation SLR pulses. The approach allows to obtain artefact-free short echo-time spectra of the frontal lobe at 3 Tesla. As compared with the use of conventional sinc3 pulses for localization, significant spectral information can be saved from the 3.5-4.5ppm range where frequency shifted water residuals arising from B_0 inhomogeneous regions can dramatically alter the spectrum quality. This approach should prove useful for short TE spectroscopy of brain regions located in the vicinity of B_0 inhomogeneities, such as the frontal lobe, the temporal lobe and the striatum.

References

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