Design and Achievement of a 2D Fast Spin Echo Pulse Sequence in Proton Electron Double Resonance Imaging

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Introduction

Proton Electron double resonance imaging (PEDRI) [(1)] based on the Overhauser effect is a promising double resonance technique enables detection of free radicals in biological samples. Proton nuclear resonance signal is enhanced by the coupled electron spin energy that is saturated by a corresponding RF source. In order to maximum the enhancement, a typical 3 x proton T1 time is needed for EPR irradiation before regular NMR signal excitation and detection. PEDRI has been performed by using standard gradient echo (GE) pulse sequence [(2)] or some ultra-fast pulse sequences [(3)]. But for the standard GE cases, each phase encoding step need a pre-EPR excitation pulse which results in long acquisition time and high SAR. In later cases with ultra-fast sequences, they are usually limited by hardware specifications such as gradient strength and slew rate and especially those pulse sequences are very sensitive to the magnet field that only can be satisfied by very well performance super-conducting coil. And normally ultra-fast sequences will scarify SNR and will induce some artifacts which needed to be corrected by special software. At this early stage of our research program, we try to develop workable and suitable PEDRI pulse sequence which can balance the specific absorption rate (SAR), TIME, SNR and hardware limitations. As a result, redesign and modification the standard MRI 2D fast spin echo (FSE) sequence can serve our purpose very well.

Methods and pulse sequence

At our fixed-field PEDRI experiment of 20.1 mT, 400 ms has been evaluated as an appropriate EPR irridiation time *in vivo* to induce the overhauser effect (for phantom experiments 600-800 ms will be the idea irridiation time). Efforts were taken to program the new pulse sequences and the image displaying window. As we can see in figure 1A, 400 ms EPR irridiation pulses with adjustable power ,length and frequency (567 MHz was chosen in this case) were added/implemented before the regular MRI FSE sequences. Read and slice gradient slice compensations can either pre or post the 180 degree pulse. During each TR period, 8 or 16 echoes were collected to rapidly cover the NMR k space. So by this way the enhanced NMR signal can be detected much more efficient than stand GE sequences or spin echo sequence. The acqusition time was reduced by 8 times or 16 times correspondely. The image reconstruction process is typical that a view reorder table is created (related to effect TE/base TE, views per segment and total number of views) before reconstruction. And since the pulse consists of one 90 degree RF pulse followed by several 180 degree RF pulses to generate multiple echoes within the T2 time frame of protons, comparing to other single-shot Ultra-fast T2 weighted imaging pulse sequences (such as EPI), this sequence is much less prone to field fluctuation and inhomogeneity.

Results

An improved EPR-NMR double resonator (high temperature stability and capability of fast tuning and coupling) was used. One slice 2D PEDRI FSE image was obtained in less than 4 s with total EPR irradiation of only 1.6 s. Comparing FSE-PEDRI images in figure 1B a ~d to standard GE-PEDRI phantom images in figure 1B (e) of four 2 mM TEMPONE tubes (diameter of 1.1 cm) surrounded by water (not seen due to the large signal enhancement of the TEMPONE), similar SNR of 140~200 were obtained despite the much shorter acquisition and EPR irradiation times of the FSE-PEDRI sequence. ACQ time: **a**, **b** 3.2 s; **c**, **d** 5s; **e**, 40 s. EPR irradiation time: **a**, **c** 1.6 s, 12 W; **b**, **d** 1.6 s, 16 W; **e** 25.6 s, 12 W. NMR frequency: 856 KHz, EPR frequency: 567 MHz, Receiver bandwidth: 10 KHz, Slice thickness: 10 mm, FOV: 6 cm, Matrix: 64x64.

Conclusion

A fast PEDRI pulse sequence based on 2D FSE has been developed. Good SNR and lower SAR with high temporal resolution were achieved. *In vivo* experiments will be followed. By further research, PEDRI should be able to take more advantages from well developed MRI fast pulse sequences.

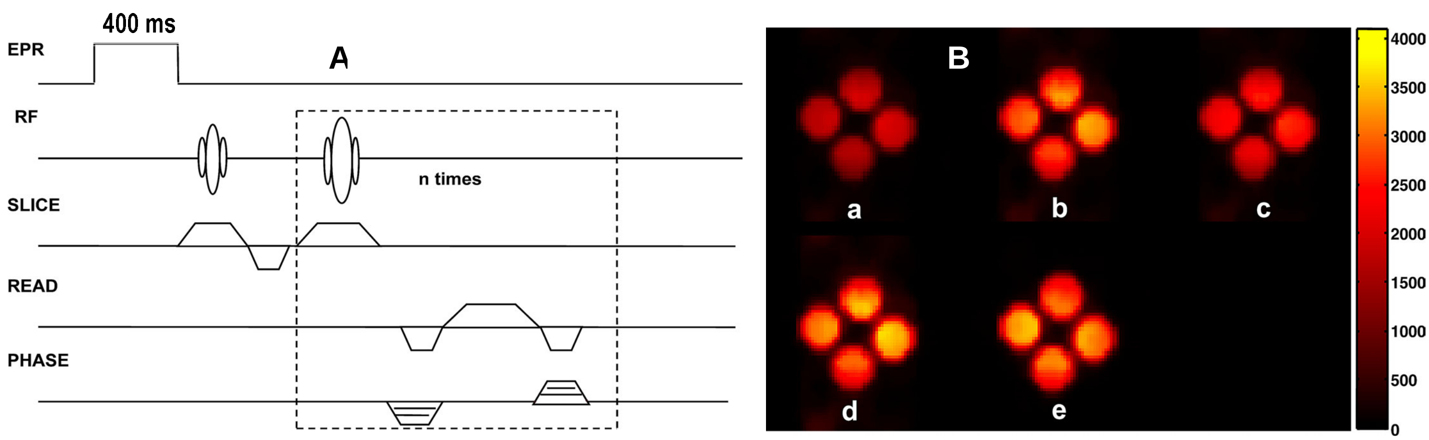

Figure 1 A: FSE2D sequence for PEDRI experiments **B:** Comparison between FSE-PEDRI images (a-d) and GE-PEDRI phantom image (e)

Reference

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