Novel contrast mechanism via ParaHydrogen SElf Rfocussing

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Introduction

A major challenge in molecular imaging is the detection of tiny amounts of interesting molecules. In magnetic resonance imaging (MRI) their signals are usually concealed by the large background signal of the body. Hyperpolarization can overcome this issue by increasing the nuclear magnetic resonance (NMR) signals up to five orders of magnitude. For the most widely used NMR and MRI nucleus ^{1}H, however, this strategy is limited. The enormous number of thermally polarized protons in the body screens the small amount of hyperpolarized ones. A simple approach is described solving this problem leading to a novel NMR/MRI contrast. It makes use of different temporal evolution of the antiphase signal of hyperpolarized ^{1}H compared to that of the thermal signal of the background. This special kind of hyperpolarization is generated via Parahydrogen Induced Polarization (PHIP)[1][1-7]. By choosing an optimal delay time for detection of the PHIP antiphase signals this new contrast can be simply implemented in any MRI pulse sequence.

Experiments

A typical sample tube for the imaging experiments contained: 500 mg 1-hexyne and 10 mg hydrogenation catalyst dissolved in 2600 mg of acetone-d6 (99.9% D). After pressurizing the tube with 3.5 bar of enriched p-H_2 outside the tomograph stray field it was subsequently moved into the magnetic field and shaken, thus starting the parahydrogenation reaction. After placing the NMR sample tube inside the phantom (depicted in Figure 1) the MRI experiments were performed (1.5 Tesla Magnetom Sonata and small finger coil, Siemens Medical). The resulting images (gradient echo sequence) were corrected by a factor corresponding to the initial hyperpolarization.

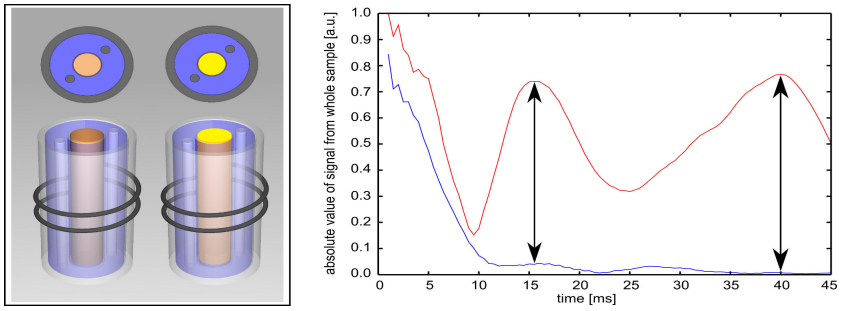

Figure 1: Left: three dimensional scheme of the phantom used for MRI experiments. Center tube is filled with PHIP substance (orange), outer tube contains water (blue). Right: the FIDs originating from the whole phantom. The blue signal stems from thermally polarized water and thermally polarized PHIP substanc. The red signal is generated by thermally polarized water and hyperpolarized PHIP substance exhibiting an antiphase NMR signal.

Results & Discussion

Figure 2 clearly shows that the intensities of the thermally and hyperpolarized regions of the images at different refocusing times (in the sequence equal to echo time TE) exactly follow the temporal evolution of the corresponding FIDs. For the water region (outer area) of the phantom the signal intensity is maximal for the shortest refocusing time. In contrast the image intensity of the PHIP area is low in the beginning and shows two pronounced maxima for 15 ms and 42 ms. As the signal of the water region almost completely decays within 10 ms, the PHIP images acquired at the maxima of the FID show excellent contrast to the thermally polarized background. These experiments thus verify that simply varying a pulse delay is sufficient to generate outstanding contrast.

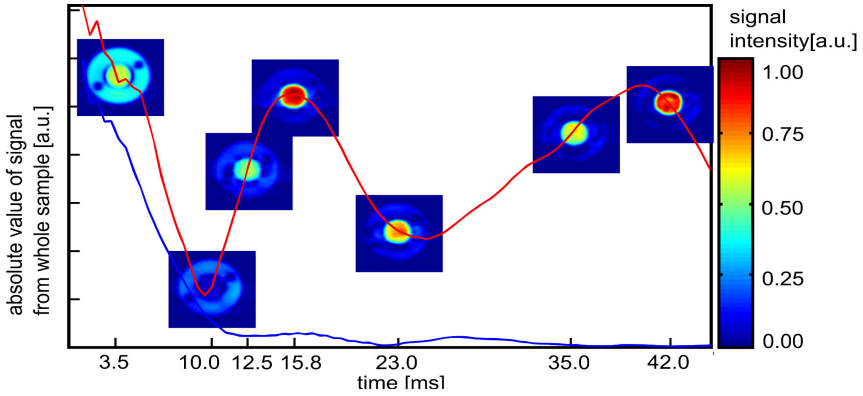

Figure 2: MR-images acquired with different echo times overlaid on thermally and hyperpolarized FIDs from Fig. 1. Imaging was performed by using a gradient echo sequence with centric reordering and the following parameters: flip angle: 10°, repetition time: 45 ms, bandwidth : 600 Hz, FOV: 50 mm^2, resolution: 0.7 mm/pixel and total acquisition time: 3.96s.

Conclusion

In conclusion, we have developed a novel MRI contrast (ParaHydrogen Antiphase Self Refocussing, PHASER) which allows for selective detection of a small number of hyperpolarized protons with an antiphase NMR/MRI signal in the presence of a large number of thermally polarized protons [2]. The contrast arises from the different time evolution of the antiphase proton signal compared to the thermal proton signal. PHASER can be used with all commonly applied imaging sequences, by just choosing optimal refocusing times for the antiphase signal.

References

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[2] Münnemann, Dechent, Schreiber & Spiess. Improved NMR measurement based on antiphase signals. Patent application: PCT/EP 2009/009195 (2009).