Beyond Relaxation Contrast: Agents for Polarization Enhancement in MRI

J. Steffan Petersson[1]
[1]Amersham Health, Malmö, Sweden

Synopsis

Two 13C polarization techniques have been developed. The achieved degree of polarization, measured after dissolution in water, was > 35% - a factor 105 above the thermal equilibrium polarization at 1.5 T. The 13C image quality was evaluated in a series of animal experiments performed in a 1.5 T scanner using a true-FISP pulse sequence. The generated images demonstrate a high CNR indicating that this new class of hyperpolarized CM may be used to visualize parts of the vascular system, including the coronary arteries, together with physiological parameters (e.g. perfusion information) during MRI.

Introduction

Hyperpolarized (HP) noble gases (^{129}Xe, ^{3}He) dissolved in lipid solution or encapsulated in micro bubbles have been proposed for use as contrast medium (CM) for vascular imaging. Instead of dissolving a hyper polarized gas our research group has focused on performing a direct polarization of the ^{13}C nucleus within water soluble molecules.

Polarization methods

Two ^{13}C polarization techniques have been developed. In the first method, a hydrogen molecule, in the para-state, is introduced into the organic molecule in question. By performing a diabatic magnetic field cycling on this highly ordered spin system we have been able to increase the signal from the small organic molecule by several orders of magnitude. The second method is based on a Dynamic Nuclear Polarization (DNP) process. The organic molecule is mixed with a stable free radical, placed in low temperature environment (~ 1 K) and exposed to a moderate magnetic field (~ 4 T). The high degree of polarization of the unpaired electrons, is then transferred to the ^{13}C nucleus in the target molecules.
The para-hydrogen method is limited to molecules comprising a double or triple C-C-bond while the DNP-methods may be applied to a large number of different classes of molecules. The degree of polarization achieved is > 35%, which is more than a factor of 10^5 above the thermal equilibrium polarization at 1.5 T.

Imaging methods

In order to evaluate the ^{13}C image quality a pig animal model (25-35 kg) was used in a series of experiments. A 1.5 T scanner (Magnetom Sonata, Siemens Medical Solutions) equipped with multi nuclei extension together with a custom built transmit/receive ^{13}C coil (RapidBiomedical, Germany) was used in all experiments. Standard proton scans were used in order to select projection angles for the FOV in question. The hyperpolarized ^{13}C CM bolus (4 ml solution, 0.3 M, ~30% polarization) was injected during MR projection imaging using a true-FISP pulse sequence.

Results and Conclusions

Figure 1a and b demonstrate two lung images, from a series obtained after an i.v. injection of a hyper polarized CM bolus. The time points after the injection are indicated. Figure 2a and b show two out of a series of non-gated images generated during an injection into the left coronary artery. The high CNR is clearly demonstrated. In the fig 2b image the ^{13}C-CM shows the myocardium, suggesting that perfusion data may also be extracted in addition to the angiography.

Two ^{13}C polarization methods have been developed. Both makes it possible to generate a contrast media in liquid form with a degree of polarization > 30%. The ^{13}C-CM may be used to visualize parts of the vascular system, including the coronary arteries, during dynamic MRI.