Magnetic susceptibility matching at the air tissue interface in rat lung using hyperpolarized gas and super paramagnetic contrast agent

A. Vignaud[1], G. Guillot[1], L. Darrasse[1], X. Maitre[1], E. Durand[1], L. de Rochefort[1], P. Robert[2], V. Vivès[2], R. Santus[2]
[1]U2R2M CNRS UMR8081, Orsay, France, [2]Guerbet Research, Aulnay-sous-bois, France

Introduction

The contribution of magnetic susceptibility difference between air and tissue to transverse relaxation of hyperpolarized helium-3 (HP ^{3}He) in lungs is a key issue for MRI strategies [1]. The susceptibility of air (+0.38 ppm MKSA) is mainly due to oxygen. Tissue susceptibility depends on both the parenchyma and the blood susceptibilities, both of them being close to water susceptibility (-9.0 ppm MKSA) [2]. In this work, intravenous injections of superparamagnetic contrast agent were performed in rats to modify their blood susceptibility, so as to match the magnetic susceptibility of pulmonary tissue to that of air. First results and perspectives of improvement for MRI are presented.

Materials and Methods

2 Sprague Dawley rats, 6-week old (250 g weight) were examined. They were anaesthetized, tracheotomized, catheterized and disposed supine in the scanner. UPSIO superparamagnetic contrast agent (Sinerem®, Guerbet, France) with a iron concentration [Fe] of 20mg/L was injected in the rat tail vein by 20-50 µL increments. ^{3}He was hyperpolarized by the metastable-exchange method. ^{3}He MR measurements were performed on a 1.5 T scanner (Signa GE) with a spectroscopic package. A coil adapted to the animal size was used. Pressure at the trachea was monitored during ^{3}He administration. The lungs were filled (about 11 mL) until pressure reached 50 cm of H_2O. 10 min after each contrast agent injection, a CPMG sequence with 128 echoes was used without applied gradient, at an inter π -pulse spacing t_{cp} of 20 ms. The T_{2cpmg} value was obtained from a monoexponential fit of the decay curve. For each rat, [Fe] was controlled on two blood samples taken respectively before and after the experiments.

Results

Spin echo decays were found dependent on [Fe] as shown on Figure 1. When increasing [Fe], T_{2cpmg} was found first to increase by more than a factor of 3, then to decrease (Figure 2); the longest T_{2cpmg} was found near an optimal air-tissue susceptibility match.

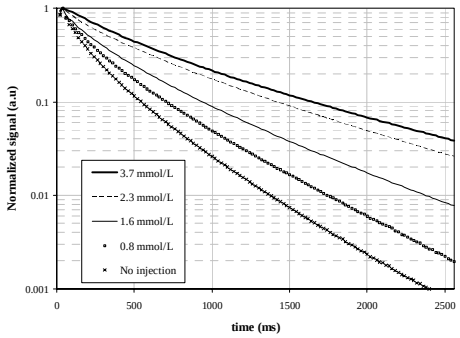


Figure 1: Normalized HP ^{3}He signal obtained with a CPMG sequence as a function of time for different estimated [Fe] in blood for one rat

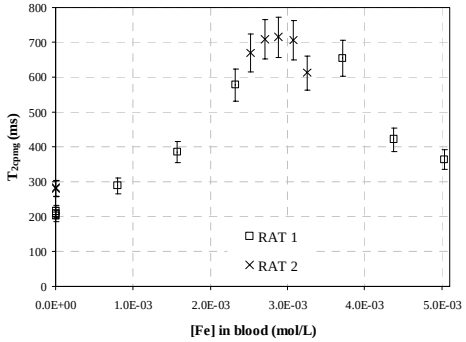
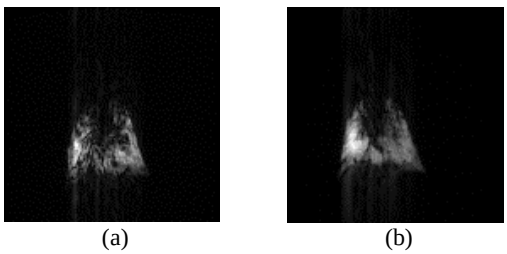


Figure 2 :HP ^{3}He T_{2cpmg} as a function of estimated [Fe] for two rats

Discussion and conclusion

The optimal [Fe] around 3.0 mmol/L corresponding to the longest T_{2cpmg} is in fair agreement with the value expected for susceptibility match (4.4 mmol/L), taking a blood volume fraction in pulmonary tissue of 0.5, as for humans [3]. Physiological differences between rats and humans could be at the origin of the remaining 33% discrepancy. FLASH images acquired with a short bandwidth exhibited strong inhomogeneities due to susceptibility defects without contrast agent (Fig. 3a), and their homogeneity was greatly improved with contrast agent near susceptibility match (Fig. 3b). Exploration of perfusion/ventilation defects at 1.5 T could be envisioned with HP ^{3}He MRI at variable bandwidth, together with contrast agents.



(a) (b)

Figure 3: Coronal FLASH lung images acquired at 1.5 T with a bandwidth of ±2 kHz on the same rat: FOV 100 mm; Slice thickness 10 mm; TE/TR=17/36 ms; matrix 128×128 :(a) without contrast agent injection (b)with contrast agent injection near susceptibility match

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References

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