SSFP BASED HIGH RESOLUTION ^{19}F IMAGING OF THE RAT LUNG EX VIVO WITH FC84

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Introduction

Partial liquid ventilation (PLV) using perfluorocarbons (PFCs) is used as a treatment of acute respiratory distress syndrome. This is mainly due to its high physical solubility for O_2 and CO_2 **1)**. Beside their therapeutic effect PFCs allow ^{19}F MRI and through their oxygen partial pressure dependent T_1 value the determination of oxygen turnover. This has been shown by Laukemper et al. **2)** and Heussel et al. **3)** in the pig lung at 1.5 T using Perfluorooctylbromid. In the rat lung Huang **4)** demonstrated the beneficial susceptibility effect on ^{1}H MRI using PLV with water-perfluorocarbon emulsions. In this work we evaluated the potential of the perfluorcarbon FC84 for high resolution ^{19}F imaging of rat lungs.

Methods

All measurements where performed on a 9.4 Tesla Bruker BioSpec animal system with a BGA 12S gradient allowing 600 mT/m and a 72 mm inner diameter, double tuned, ^{1}H/^{19}F, linear birdcage resonator. The perfluorcarbon tested for imaging was FC84 (C_6F_{14}) from 3M™.

Localizer scans as well as all adjustments where done using the ^{19}F channel. The relaxation measurements where performed on pure FC84 in a standard 50 ml tube at room temperature. A standard PRESS sequence with a voxel size of 40x40x40 mm was employed for the relaxation measurement using TE: 16 ms, and TR's ranging from 100 to 10,000 ms for the T_1 and furthermore TR: 10 s and TE's ranging from 16 to 256 ms for the T_2 evaluation. The spectra where post processed in Topspin™ employing a baseline correction, a line broadening of 2 Hz an FT and a manual phase correction before integration of the prominent main singlet peak. The values derived from the integration where then fitted mono-exponentially as seen in Fig. 2.

Calculation of expected signal intensities as well as required optimal flip angles of different gradient echo methods was performed according to the work of Scheffler et al. **5)**.

Care and use of laboratory animals followed the national guidelines and was approved (35/9185.81/G-07/01) by the institutional animal care and ethics committees of the University of Freiburg, Germany.

A 500g wistar rat was sacrificed and the lung was excised. It was placed in a 50 ml tube and filled with FC84 until the lung fitted tightly to the tube which served as a chest wall replacement. The trachea was then tied up and the complete tube was filled with FC84.

For imaging the frequency was tuned to the main singlet in the FC84 spectrum. The 3D-PSIF sequence was run with a TE / TR of 6.4 / 12.8 ms a flip angle of 40.8°, a FOV of 45x36x28 mm and a matrix of 256x256x128 leading to a resolution of 176x141x219 µm. Due to an eightfold averaging the acquisition time resulted to 28 min 44 s. In order to avoid chemical shift artifacts the excitation pulse bandwidth was 2 kHz with an effective spectral bandwidth of 50 kHz and the slice direction was chosen parallel to minimum FOV direction.

Results

The relaxation fits of the spectral singlet plotted in Fig. 1 at 20 ppm lead to a longitudinal relaxation T_1 of 1548 +/- 16 ms and a T_2 of 268.3 +/- 35 ms (Fig. 2). Utilizing these values and the TE/TR of 6.4 / 12.8 ms mentioned above the calculated intensities of numerous gradient echo sequences are displayed in Fig. 3. As expected the most signal intensity is gained with TrueFISP, but FISP and PSIF still yield double the intensity of a common FLASH sequence. Chemical shift artifacts due to the other resonances of FC84 where successfully avoided through the bandwidth selections stated in the methods chapter and the high resolution PSIF maximum intensity projection reveals bronchial tubes up to the 3rd generation (see Fig. 4). Note that the trachea became detached from the bronchi during preparation.

Discussion

The comparably high T_2/T_1 ratio suggests SSFP based sequences for fast high resolution imaging. For this work TrueFISP was not considered due to its strong banding artifacts at 9.4 T. However, these first results gained with a SSFP based sequence convincingly demonstrate the feasibility of high resolution ^{19}F MRI in the rat lung. Further work will transfer the method to in vivo application in order to monitor volume changes of the central airways during changing lung volume.

Literature

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3) Heussel CP et al. Invest. Radiol. 2003 38(10):635-41
4) Huang MQ et al. Magn.Res.Med. 2002; 48:487-92
5) Scheffler K. Concepts In Magnetic Resonance, 1999. 11(5):291-304

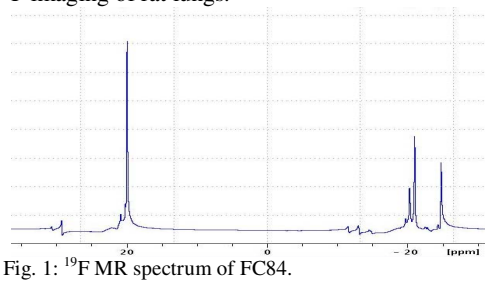

Fig. 1: ^{19}F MR spectrum of FC84.

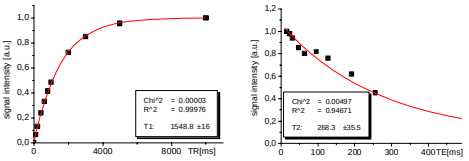

Fig. 2: Relaxation times of FC84 at 9.4 Tesla and room temperature are in the order of 1550 ms for T_1 and 270 ms for T_2.

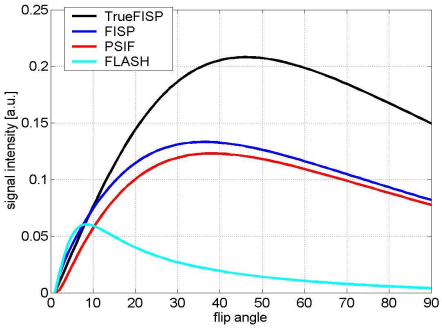

Fig. 3: Flip angle dependent signal intensities for various gradient echo sequences.

Fig. 4: Maximum intensity projection of a 3D -^{19}F - PSIF ex vivo rat lung image.