In vivo Oxygen-17 (17O) MRI at 7 Tesla

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Introduction

Oxygen-17 (^{17}O) MRI is a promising tool for assessing in vivo metabolic tissue information at ultra high fields [1]. It has been shown that oxygen consumption can be determined by detection of the signal increase due to inhalation of enriched ^{17}O gas. However, ^{17}O-MRI suffers from low inherent SNR because of the low natural abundance (0.037%) and short relaxation times of the ^{17}O nucleus (I = 5/2). Hence non-cartesian imaging techniques with short echo times are necessary for SNR efficiency. In addition, an efficient and accurate gas delivery system for the enriched ^{17}O gas is needed that makes efficient use of the expensive gas. In this work direct ^{17}O imaging experiments were performed in vivo with natural abundance ^{17}O as well as in an inhalation experiment with enriched ^{17}O gas using an inhalation-triggered breathing system.

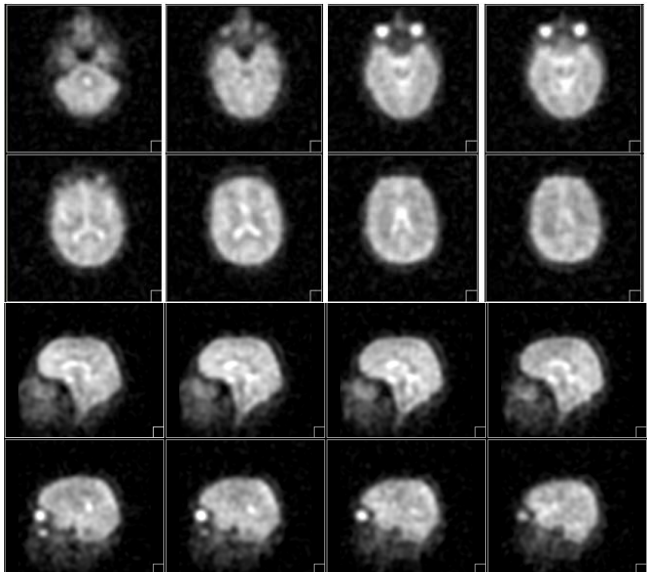

Fig. 1: Natural abundance ^{17}O images (Hanning filtered) acquired in 10 minutes with an isotropic spatial resolution of 5mm.

Materials and Methods

Direct ^{17}O-MRI was performed on healthy volunteers on a 7 Tesla MR system (Magnetom 7T, Siemens Medical Solutions, Erlangen, Germany) using a custom built ^{17}O-Tx/Rx-coil. The coil was a modified 1 Tesla ^{1}H quadrature head coil which was tuned to the ^{17}O resonance frequency of 40.28 MHz.

Natural abundance ^{17}O-MRI was carried out using a density-adapted 3D projection reconstruction sequence (DA-3DPR) [2] with the following imaging parameters: TR = 12 ms, TE = 0.6 ms, α = 32°, BW = 150 Hz, 10000 projections, 5 averages, T_{AQ} = 10 min.

In vivo relaxation times were determined using global spectroscopic sequences.

In an ^{17}O inhalation experiment 70% enriched ^{17}O gas was administered with a commercial inhalation-triggered breathing system (Oxytron3, Weinmann, Hamburg, Germany) which was designed for efficient oxygen administration (e.g., in mountaineering). The system detects the beginning of the inspiration and delivers the gas to the patient in an early inspiration phase. The ^{17}O gas was delivered to a volunteer for an inhalation period of 4 minutes at a rate of 40 ml gas per breath. Direct ^{17}O imaging was performed for 28 minutes prior to, during and after inhalation using the DA-3DPR sequence. Projections were acquired in interleaved spokes order of 8 isotropic k-space data sets per average. This k-space order allows for SNR enhancement by averaging of time frames, but also enables high resolution imaging with the HYPR reconstruction algorithm. Imaging parameters for the inhalation experiment were TR = 6.6 ms, TE = 0.45 ms, α = 24°, BW = 200 Hz, 6000 projections, 5 averages (8 time frames per average), resulting in an isotropic spatial resolution of 8mm.

Results and Discussion

Figure 1 shows representative slices from a natural abundance ^{17}O 3D data set. The Hanning-filtered images show a mean SNR of 16 averaged over the whole head. In vivo relaxation times of T_1 = 6.7±0.4 ms, T_2 = 2.1±0.1 ms and T_2^* = 1.5±0.1 ms were found for the human head.

The results of the ^{17}O inhalation experiment with a temporal resolution of 41 seconds are displayed as the integrated intensity data of the brain (Fig. 3). A volume of 1.2±0.2 l of enriched ^{17}O was delivered to the subject. Oxygen supply was switched off 10 minutes after start of the image acquisition. A decrease in signal intensity is visible when oxygen-17 supply was switched off, which was not seen in reference vials in the imaging volume. Thus, the weak intensity modulation arises from the inhalation and metabolization of the enriched ^{17}O gas. Further studies concerning the needed amount of enriched gas need to be carried out for detection of a sufficient signal increase for model based data fitting.

We have shown that direct imaging of natural abundance ^{17}O in vivo is possible in 10 minutes at 7 Tesla and a signal increase was detected in an ^{17}O inhalation experiment.

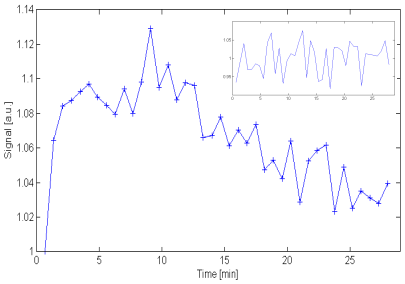

Fig. 3: Integrated signal intensity of the brain vs time for a 4 minute period of enriched ^{17}O inhalation and subsequent signal decrease. The signal of a reference vial is shown in the upper right corner.

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References

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