Direct cerebral 17O-MRI at a clinical field strenght of 3 Tesla using a Tx/Rx head coil

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Introduction

Many diseases such as Alzheimer's, myocardial infarction or tumors, alter the oxygen consumption and metabolism, and a method for the quantification of the local oxygen metabolic rate would be desirable. Oxygen-17 provides functional tissue information by assessing oxygen turnover *in vivo* noninvasively [1]. To partially compensate for the low MR sensitivity of ^{17}O which is 1.08×10^{-5} fold lower than ^{1}H [2], the first direct ^{17}O *in vivo* study in human head was performed at ultra-high fields [3]. Unfortunately, high-field MR systems with $B_0 \geq 7$T are not available in clinical routine so far, which severely limits the applicability of this technology. Recently the feasibility of direct cerebral and cardiac ^{17}O-MRI at natural abundance at clinical field strength of 3 Tesla has been demonstrated [4, 5]. Based on these results, in this work ^{17}O MRI with a transmit/receive (Tx/Rx) ^{17}O head coil is presented.

Materials and Methods

A four leg low pass birdcage coil (diameter Ø = 27 cm) from a 1.5 T MR system was re-tuned to the Larmor frequency of ^{17}O ($f_0 = 16.7$ MHz) at 3 Tesla. Each leg was split with a capacity $C = 6.8$ pF to reduce eddy currents. The loaded volume coil was tuned and matched in the 3T MR system (Tim Trio, Siemens Healthcare, Erlangen, Germany) with a portable network analyzer (VIA ECHO MRI, AEA Technology Inc., Carlsbad, CA) to compensate the frequency shift of $\Delta f = +228$ kHz which was observed when the coil was placed inside the magnet. The coil was connected to a custom-built Tx/Rx switch including a modified preamplifier (gain = 26 dB, noise figure $N_f = 1$ dB).

After testing the coil performance in phantoms, several 3D UTE data sets of the brain were acquired in a healthy 47y-old male volunteer using the following imaging parameters: TE = 0.92 ms, TR = 8 ms, $T_{pulse} = 1.6$ ms, BW = 250 Hz/pixel, $T_{RO} = 4$ ms, $\alpha = 76°$, 300 averages, FOV = (360 mm)^2, 501 projections x 64 sample points per projection, nominal resolution (5.6 mm)^3, matrix: 64 x 64 x 64, $T_{AQ} = 20$ min. The relatively long pulse duration was required due to SAR restrictions. Additionally, ^{1}H 3D MPRAGE data were acquired for anatomical comparison with the following parameters TE = 2.86 ms, TR = 2300 ms, TI = 1100 ms, BW = 130 Hz/pixel, $\alpha = 12°$, 1 averages, FOV = (262 x 300) mm^2, SL = 1 mm, nominal resolution (0.6 x 0.6 x 1) mm^3, matrix: 448 x 512, $T_{AQ} = 8{:}36$ min.

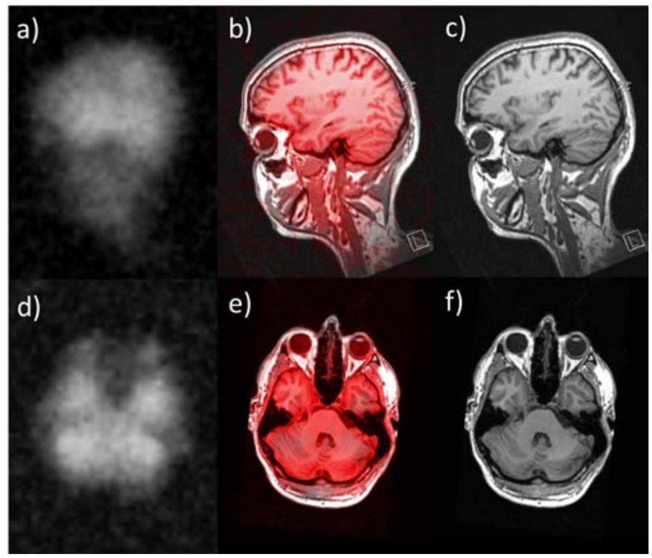

Fig. 1*: Manually co-registered ^{17}O (a, d), ^{1}H (c, f) and fused images (b, e,) in sagittal and transverse orientation. At a nominal isotropic resolution of (5.6 mm)^3, a mean $SNR_{mean} = 16$ was achieved with ^{17}O at natural abundance of 0.037% in a measurement time of 20 min. The images were acquired with a 3D-UTE radial pulse sequence and a 3D MPRAGE, respectively.*

Results and Discussion

Figure 1 shows a selected sagittal and transversal slice from the ^{17}O data set (Fig. 1a, d) together with the manually co-registered ^{1}H data (Fig. 1c, f). In the fused view of both data sets (Fig. 1b, e) a good correspondence between the anatomical regions can be seen. In the fused image the fluid-filled eyes can be clearly identified as a hyperintense region (SNR = 7) in both slices (Fig. 1a, d).

In this work, direct ^{17}O-MRI of the brain was performed at natural abundance. ^{17}O-MR 3D data sets were acquired on a clinical 3T system using a linear Tx/Rx birdcage and an adapted UTE pulse sequence. In the future, to provide a higher SNR with the volume coil and better B_1-homogeneity [6] a quadrature hybrid is under construction to operate the head coil in quadrature mode. This will lead to an SNR gain by a factor of 1.4 and allows reducing the measurement time down to 10 min. In combination with a dedicated delivery system for enriched ^{17}O gas these results are a first step towards measurements of the oxygen metabolic rate in a clinical setting.

References

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