Natural abundance *in vivo* ^{17}O measurements at 9.4T

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Target Audience: Basic researchers who are interested in X-Nuclei imaging and molecular imaging.

Introduction and Purpose

In diseases such as Alzheimer's, the cerebral metabolic rate of oxygen consumption ($CMRO_2$) is already known to show changes[1,2,3]. Thus, the knowledge of quantitative values of $CMRO_2$ is of great interest to follow the treatment of the disease. In addition, changes in $CMRO_2$ are an active area in diabetes research where the central nervous system is thought to play an integrative role. In the last decades, radioactive tracers such as ^{15}O were used to quantify $CMRO_2$ with PET imaging and this is regarded as the gold standard. However, such methods are complicated and expensive as a consequence of the short half-life (2 min) of ^{15}O and inherently include radiation exposure. Direct measurements of increased oxygen metabolism and a detailed knowledge of quantitative values for $CMRO_2$ derived from NMR/MRI experiments may help to study brain activity in disorders such as the ones alluded to above. Unfortunately, the most abundant isotope of oxygen (^{16}O) is a zero spin system, and cannot be detected with NMR experiments. In contrast, ^{17}O, is a stable isotope with a half-integer spin (I=5/2) that can be detected by MR. Fortuitously, however, it is only visible in the form of metabolically generated $H_2{}^{17}O$ and not as gas. The low natural abundance of ^{17}O, of only 0.038% (of the oxygen atoms) and the low NMR sensitivity (2.9% that of ^{1}H) give rise to the need for Ultra-High-Field MRI to reach a significant SNR per unit time. In this preliminary study we demonstrate the feasibility of *in vivo* ^{17}O imaging experiments with a sufficient SNR in acceptable measurement times. Moreover, the experiments were carried out in a 9.4T scanner capable of hybrid MR-PET operation; the very preliminary results reported here are thus a first step in creating an experimental protocol capable of using ^{15}O-PET as a gold standard and calibrating MRI against it for future quantitative evaluation of $CMRO_2$ without the need for radioactive ^{15}O.

Methods

Natural abundance images of a healthy male volunteer were acquired *in vivo* after having gained written consent within a clinical trial of a 9.4 T MRI system (Siemens AG, Erlangen, Germany). A homebuilt circularly polarized birdcage coil tuned to the ^{17}O Larmor frequency of 54.2 MHz at 9.4 T with an inner diameter of 280 mm and a length of 240 mm was used for transmission and reception (Fig. 1). A home-written twisted projection imaging sequence (TPI)[4] was used for the measurements. The sequence parameters were: TE=0.4ms, TR=11.4ms, readout time=5.12ms. The maximum specific absorption rates (SAR) limit imposed the use of a flip angle of 30 degree. Using these sequence parameters we acquired two sets of data. The first data set had a nominal resolution of 5mm isotropic and was obtained with 10 averages in 11 min and 19 seconds. The second data set had a nominal resolution of 10 mm isotropic and was obtained with 8 averages, which took 1:01 min each.

Results

The measured rawdata was regridded to a Cartesian grid using a standard gridding algorithm written by N. Zwart and J Pipe and freely available at [5]. To improve the SNR, a blackman filter was applied to k-space data of the 5mm measurements. Representative slices of each measurement can be found in Figures 2 and 3 respectively.

Figure 1: Tx/Rx ^{17}O Coil

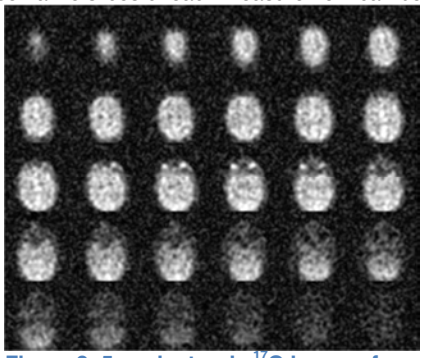

Figure 2: 5mm isotropic ^{17}O image of a healthy volunteer

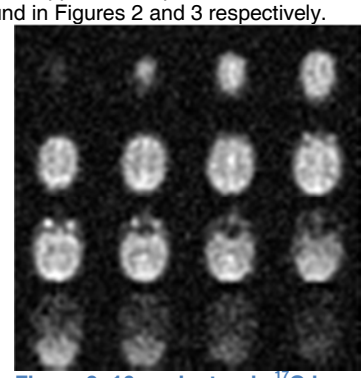

Figure 3: 10mm isotropic ^{17}O image of a healthy volunteer (average of all measurements)

Discussion / Conclusion

In this preliminary study it has been shown that it is possible to acquire ^{17}O images in clinical acceptable measurement times in a 9.4T scanner that is capable of hybrid MR-PET. Further developments will allow us to perform inhalation experiments of ^{17}O, which enables $CMRO_2$ quantification and compare these to the gold standard ^{15}O measurements from *simultaneous* MR-PET. Simultaneously performed PET and MR measurements at 9.4T will enable a valuable comparison and thus pave the way for the use of non-radioactive ^{17}O MRI for the evaluation of $CMRO_2$ in a variety of diseases.

References

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