Field Shift due to Paramagnetic Effect of Molecular Oxygen

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Introduction:

Oxygen inhalation has the benefit of being minimally invasive, inexpensive, and widely available, in addition to having high tolerability and fewer contraindications compared to alternative techniques. Hyperoxia has been shown to be a simple and effective positive contrast agent in T_2*-weighted images based on the BOLD effect. It has been proven to be useful tool for a number of applications, including the calibration of quantitative BOLD fMRI and the quantitative measurement of regional capillary-venous cerebral blood volume (CBV). However, paramagnetic effect of molecular oxygen could shift the static field, which is unrelated to blood oxygenation and confounds the observed MRI contrast. The objective of this study is to characterize the field shift due to oxygen inhalation in case of small animal MRI setup at high field, 9.4T.

Methods:

Fisher rats (F344/NCR, 6-8 weeks old, n=4) were imaged at a Varain 9.4T small animal MRI scanner with a 35-mm diameter commercial quadrature proton coil. Rats were anesthetized with 1.5% isoflurane and given different percent of oxygen (100%, 80%, 60%, 40%, 21% and 8% diluted with corresponding amount of nitrogen) through a nose cone. After each gas were given for 2-3 mins, non-water suppressed single voxel spectroscopy (SVS) from a voxel (6mm*6mm*6mm) located in the center of rat brain was acquired by using a STEAM sequence with TR=6s, TE=9ms. A B_0 field map was obtained using four complex gradient echo images (TE = 2.5, 3.0, 3.5, and 4.0 ms) by fitting the linear relationship between phase differences and echo time differences. The animal procedures are conducted under an approved protocol of the institutional animal care and use committees.

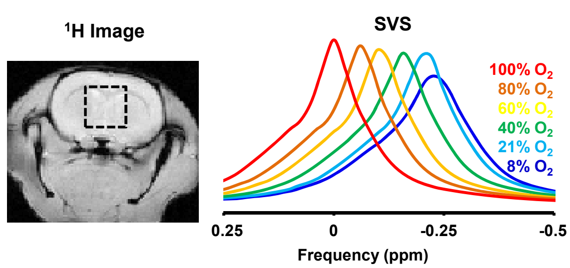

Figure 1. SVS (right) of a central brain voxel (shown as a dashed box from the proton image, left) collected during different percent of oxygen.

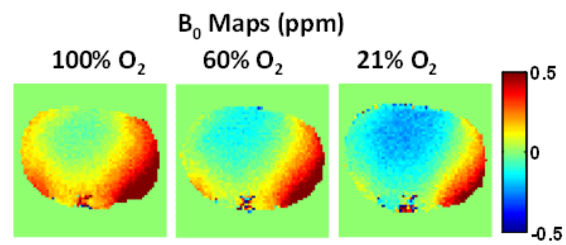

Figure 2. B_0 maps of a rat brain during 100%, 60% and 21% of oxygen.

Results:

Both SVS (Figure 1) and B_0 maps (Figure 2) acquired at different oxygen inhalation show that field shift due to oxygen gases. From 8% to 100% oxygen, proton frequency shifts by up to ~0.25ppm. Figure 3 shows a linear relationship between field shift and percentage of oxygen inhalation with a slope of ~1 Hz per 1% of oxygen at 9.4T. Similar effects were seen from a dead animal with the same inhalation setup.

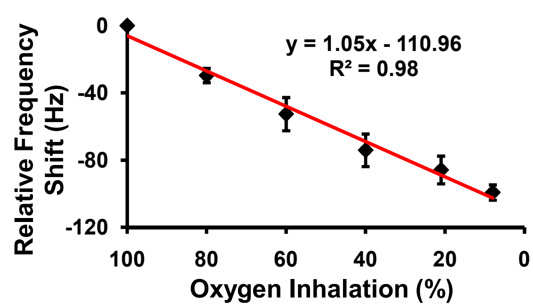

Figure 3. Field shift in Hz as a linear function of oxygen inhalation.

Conclusion:

We have characterized the static field shift due to paramagnetic effect of molecular oxygen at 9.4T by using SVS and B_0 maps. Proton Larmor frequency is shifted up to 0.25 ppm or 100Hz in 9.4T at the small animal ventilating setup. One must be cautious on this confounding factor when conducting fMRI and field sensitive MRI studies with oxygen inhalation.

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