Effects of Oxygen-enhanced fMRI in the Resting-state Networks

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Abstract

Functional neuroimaging of the resting-state in humans has gained increased interest during recent years, especially functional Magnetic Resonance Imaging (fMRI). Resting-state fMRI investigates the temporal correlations of the blood oxygen level dependent (BOLD) signals without any specific task. The low-frequency baseline fluctuations (0.01-0.1 Hz) are believed to be the regulation of the blood flow from the neurovascular mechanisms. They are presumed to reflect the intrinsic functional connectivity of the brain. Oxygen as an MR contrast agent (Oxygen-enhanced magnetic resonance imaging) has been used in recent years to investigate its effect on brain function in normal controls as well as epilepsy [1, 2]. However, no previous work has studied the effect of oxygen on resting-state fMRI in human. The aim of this study is to investigate the difference in activation in the resting-state networks in healthy control subjects when performing the scans with and without oxygen enhancement.

Method

Oxygen-enhanced MRI:

Oxygen was used as an MR contrast agent, and delivered to the subject through a cannula. During the resting-state acquisitions, subjects were instructed to let their minds wander but refrain from any cognitive, language or motor tasks as much as they could. Two scans were performed, one with the subject breathing ambient air in the room, and in the second scan the subject was breathing 100% oxygen through a cannula throughout the duration of the scan.

Subjects:

Normal healthy subjects participated in this research: 8 males and 18 females, aged 21-39 years of age (mean age = 26, SD = 4.3; mean age of male and female is 26.9). Each subject had 2 fMRI resting-state scans – one with oxygen and the other without oxygen, and a T1-weighted anatomical scan for anatomical coregistration and normalization.

Imaging:

Imaging was performed using a Philips 3T Gemini MRI. The fMRI data were acquired using a segmented EPI-acquisition (TR=4000ms, TE=27ms, matrix=96x96, 38 slices, thickness=2.5mm, 2 segments). A high resolution T1-weighted anatomical scan (MPRAGE) was acquired (TR=2.5s, TE=3.5ms, FOV=22.4cm, matrix=224x224, 172 slices, thickness=1mm)

Image Analysis:

Acquired functional image data were analyzed with FSL (Analysis Group, FMRIB, Oxford, UK). Preprocessing of the functional images included motion correction (MCFLIRT), co-registration to the high resolution T1-weighted images (FLIRT) and non-linear registration to the standard MNI T1 template (FNIRT). Multi-subject independent component analysis (ICA) and MELODIC [3] were used to identify 18 unique networks of the resting-state activities. Dual-regression analysis was implemented on the default mode and attention networks.

Results

We investigated the two most commonly studied networks: the default mode network and the attention/memory network. Significant differences were detected when we compared the oxygen enhanced scans versus ambient air scans. The oxygen enhanced scans showed greater significant coactivation in the anterior cingulate regions in the default mode network (Fig 1). The oxygen enhanced scans also showed greater coactivation in several of the regions of the attention network. We also analyzed the variance of the time course signal by computing the Amplitude of low frequency fluctuations (ALFF) ($p<0.01$) as well as the fractional ALFF ($p<0.04$).

Discussion

The primary purpose of oxygen on the brain is acting as a reagent in metabolic reactions. Changes in oxyghemoglobin content during brain activation is what is detected in BOLD imaging. By supplying additional oxygen we change the baseline oxygen content and thereby the baseline signal. We have previously shown that oxygen enhanced MRI modifies the relaxation parameters such as T2 & T2* which will indirectly affect the BOLD [4]. The default mode network has also been found to be a complementary (inversely correlated) network for regions that are activated with task oriented actions such as the DLPFC with working memory. On the other hand oxygen may modify the regional bloodflow, but previous studies showed that this effect may not be significant. We conclude that oxygen enhanced MRI may augment resting-state fMRI studies but further studies need to performed to investigate the nature of this mechanism.

Reference

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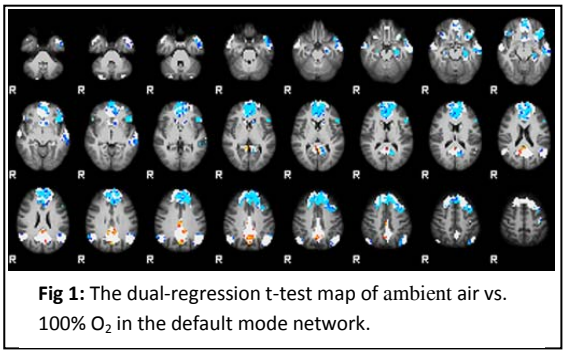

Fig 1: The dual-regression t-test map of ambient air vs. 100% O_2 in the default mode network.

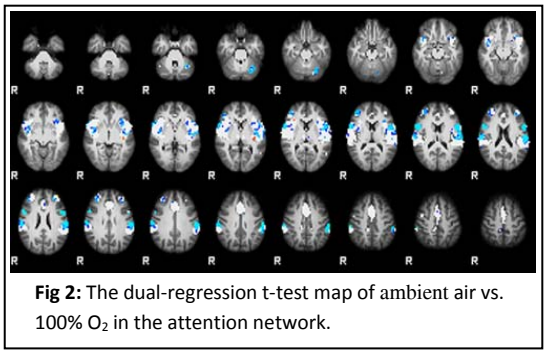

Fig 2: The dual-regression t-test map of ambient air vs. 100% O_2 in the attention network.