Intermolecular Multiple Quantum Coherences (iMQC) in Brain: A Dramatic Change in Signal with Hyperoxia

D. P. Bulte[1], L. S. Bouchard[2], W. S. Warren[2], M. D. Noseworthy[1]
[1]The Hospital for Sick Children, Diagnostic Imaging, Toronto, Ontario, Canada, [2]Princeton University, Dept. of Chemistry, Princeton, New Jersey, United States

Intermolecular multiple quantum coherences (iMQC) have been used to probe tissue structure on scales beyond those accessible by conventional imaging. Combining this technique with hyperoxia (breathing 100% O_2), to increase contrast and highlight tissue microvasculature oxygenation, yields a new method of potentially evaluating tissue function and pathology. Using a GE 1.5T CV/i MRI, intermolecular double quantum coherence (iDQC) imaging of a single axial slice through the brain lateral ventricles was performed. Hyperoxia showed a marked reproducible change in image signal (~40% in gray matter), and is more sensitive to signal changes attempted by T_1 or T_2 mapping.

Introduction

The potential use of iMQC as contrast mechanisms in MRI has been raised in recent studies [1][2]. The current theoretical framework suggests the potential for contrast in medical imaging based on dipolar interaction correlation distances (d_c), and sensitive imaging of magnetic susceptibility distributions, which are essential for functional, and oxygenation studies. Images using iMQC contrast could potentially lead to improved detection of hypoxic tumours. To assess whether this method is sensitive to oxygenation changes [3], iMQC imaging of the brain, with and without inhalation of 100% O_2 was done. As brain blood volume is of the order of 2-4%, and this treatment results in a subtle increase in blood pO_2, detection of a difference would suggest this method as a potential tool in tumour evaluation.

Methods

MRI was performed using a GE Signa 1.5T CV/i MRI with 4 G/cm gradients. A single axial slice through the brain lateral ventricles (n=4) was evaluated using a CRAZED iDQC sequence (M=+2, z-correlation gradient, τ=13ms, TE=90ms, TR=4s, 32x32 matrix, 4 NEX, cycling the phase of the first RF pulse between 0° and 180°), in the presence and absence of inspired 100% O_2 (12L/min). Three correlation distances were also compared: 83μm, 135μm, and 1.18mm. The iMQC scans were compared to changes in T_1 and T_2 relaxation using a spiral based magnetisation preparation sequence [3].

Results and Discussion

Brain T_1 and T_2 values did not significantly change with breathing of 100% O_2 indicating proton relaxation times are not likely to be useful indicators of oxygen changes within the brain (**Table 1**).

	Normoxia (ms)	Hyperoxia (ms)	% Difference
T_1 Gray Matter	949±36	947±29	-0.24%
T_1 White Matter	642±21	641±24	-0.14%
T_2 Gray Matter	109±9	107±12	-1.7%
T_2 White Matter	95±6	94±7	-0.75%

Table 1. *Brain T_1 and T_2 with and without hyperoxia exposure.*

The greatest iDQC signal observed was in gray matter at d_c=135μm. When hyperoxia was applied a large difference in the iMQC signal was seen, relative to normoxia (**Fig. 1)**. The percent change between gas states consistently ranged between 35 and 40% with this modulation being most dramatic at the lowest correlation distance examined (d_c=83μm). A consistency check was performed by repeating the experiment in 4 subjects. In addition the effect was reproducible, within the same subject, as observed by cycling inspired gas between normoxic and hyperoxic states (i.e. normoxia-hyperoxia-hyperoxia-normoxia). Adjusting the iMQC correlation distance, in the presence of hyperoxia, may allow one to gather information on what could be related to microvascular density and tissue oxygenation.

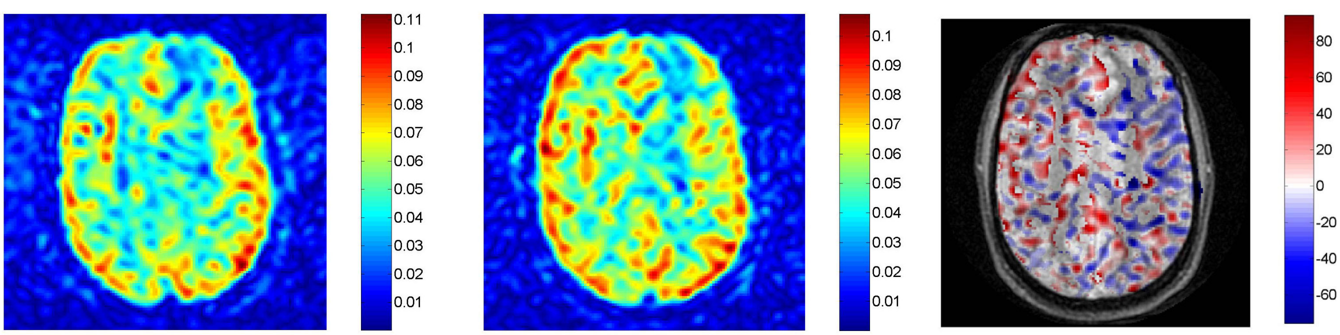

Figure 1. *+DQC image (left) in the presence of normoxia, compared to +DQC during inspiration of 100% O_2 (middle). The percent difference is overlayed on an anatomical image of the same axial slice through the brain (right). There was a ±40% change in iMQC signal in gray matter observed with hyperoxia exposure..*

Conclusion

The iMQC imaging method is more sensitive to tissue oxygenation; much more so than T_1 or T_2 mapping methods which have been attempted previously. iMQC is sensitive to tissue microstructure, as seen by the change in SNR over d_c. It is suggested that iMQC may be useful in assessing tissue microvasculature oxygenation and density.

References

[1] Zhong J, Chen Z, Kwok E. *J. Magn. Reson. Imag* . **12**:311-320 (2000); [2] Warren WS, et al, Science, **281**:247-251 (1998); [3] Noseworthy MD, Stanisz GJ, Kim JK, Stainsby JA, Wright GA. *J. Magn. Reson. Imag* . **9**:814-820 (1999).