Quantification of Regional Cerebral Metabolic Rate of Oxygen Consumption in the Middle Cerebral Artery Territory

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Introduction: The human brain predominantly relies on the aerobic metabolism of glucose to meet its enormous energy requirements [1]. A robust method for quantifying regional cerebral metabolic rate of oxygen consumption ($rCMRO_2$) would be of significant clinical utility in the workup of numerous vascular pathologies affecting the brain. For example, such a paradigm could be extended to identify patients with vascular territorial comprise at risk for ischemia or stroke. The few available MR based methods for absolute $rCMRO_2$ estimation are hampered by long scan times and complex signal models with several underlying assumptions [2]. Alternate imaging methods such as positron emission tomography (PET) are limited in their use due to invasiveness and expense [3]. Here, as an extension to the recently reported method for determining global $CMRO_2$ [4], we demonstrate the feasibility of determining lateralized $rCMRO_2$ corresponding to the middle cerebral artery (MCA) territory by measuring regional cerebral blood flow (rCBF) in the MCA and regional venous oxygen saturation (rS_vO_2) in the largest superficial cortical vein draining into the superior sagittal sinus (SSS) corresponding to the MCA vascular territory.

Methods: rS_vO_2 quantification relies on the measurement of relative magnetic susceptibility, $\Delta\chi$, of intravascular blood and surrounding tissue by modeling the vessel of interest as a long paramagnetic cylinder [3,4]. Oxygen saturation ($\%HbO_2$) is determined as $\%HbO_2 = \{1 - 2|\Delta\phi|/[\gamma\Delta\chi_{do}B_o(\cos^2\theta - 1/3)Hct]\} \times 100$ where $\Delta\phi$ is the average phase difference between intravascular blood and surrounding tissue, $\Delta\chi_{do} = 4\pi(0.27$ ppm) [5] is the susceptibility difference in SI units between fully deoxy/oxygenated erythrocytes, hematocrit (Hct) is the volume fraction of the packed erythrocytes in whole blood and θ is the tilt angle of the vessel with respect to the main field B_o. rCBF was measured in the M1 segment of MCA using phase contrast MRI. All MR experiments were performed on a 3T Siemens Tim Trio system. Scan parameters: FOV = 176 × 176 × 2 mm^3, voxel size = 0.5 × 0.5 × 2 mm^3, flip angle = 25°, TR=35ms, echo spacing = 2.5 ms, VENC = 80cm/s. A double oblique localization strategy was used to ensure measurements perpendicular to the vessels. The tilt angle of the cortical vein with the B_o field was calculated for rS_vO_2 quantification based on a double-oblique localization strategy (Figure 1). An average MCA territory volume of 230 cm^3 was used to quantify $rCMRO_2$ per 100g of brain mass [6]. Additionally, the sensitivity of the method to a task-based stimulation involving cerebral processes specific to the MCA territory was evaluated. The subject was asked to perform fine-coordinated finger movements of the right hand and count forwards and backwards while imaging of the contra-lateral side was conducted.

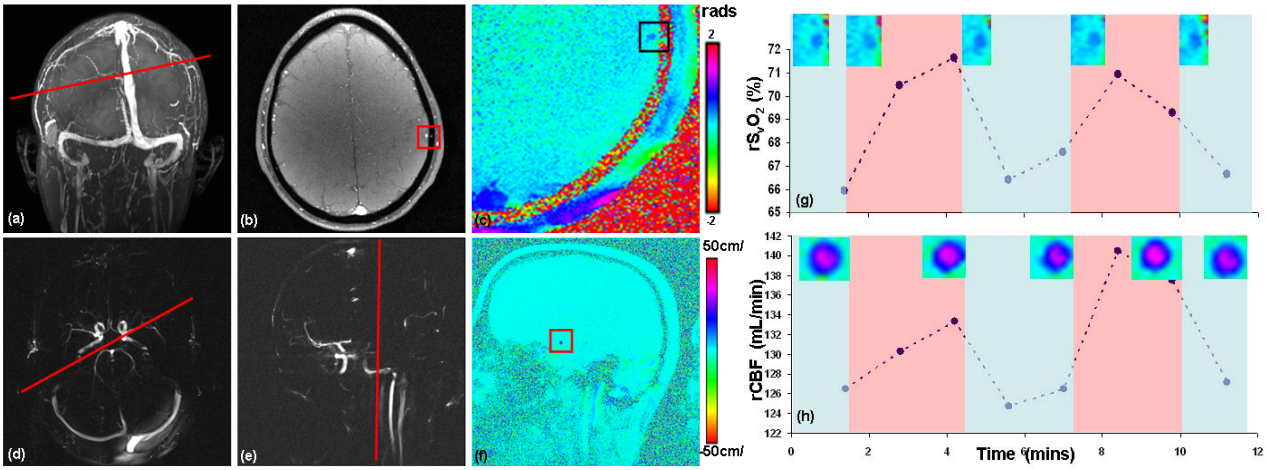

Figure 1 (a) *Coronal MIP highlighting the largest superficial cortical vein in the left MCA territory and draining into SSS;* ***(b)*** *axial magnitude image;* ***(c)*** *phase image;* ***(d)*** *angiogram of left and right MCA's;* ***(e)*** *paracoronal angiogram of left MCA;* ***(f)*** *velocity map showing MCA (square);* ***(g, h)*** *time resolved measurements of* $rSvO_2$*;* ***(g)*** *and rCBF (**h**) during a motor activation task (blue = rest; pink = task).*

Results and Conclusion: rS_vO_2 , rCBF and $rCMRO_2$ in three healthy male adults (age: 28 ± 2 years) 67±2%, 125±6 ml/min and 139±7μmol/100g/min, respectively, in agreement with previous results [7,8]. During the task based stimulation, rCBF and rS_vO_2 increased by 7.3 % and 5.8 % (**Figure 1**). Average $rCMRO_2$ during rest and task was 142±4 and 137±7 μmol/100g/min, respectively.

In conclusion, we demonstrate the feasibility of MR susceptometry-based oximetry to quantify $rCMRO_2$ corresponding to middle cerebral artery territory. Our preliminary data during a motor activation demonstrates changes in rCBF and rS_vO_2 in agreement with previous studies [3]. However, a larger sample size and the ability to determine rCBF and rS_vO_2 simultaneously will be needed to better evaluate changes in $rCMRO_2$ during task-based activation.

References

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