Multimodal Validation of Physiological MRI: Triple Oxygen PET and NIRS

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Purpose Physiological dual-gas calibrated MRI methods have been developed for measuring cerebrovascular physiology.[1] While the quantities measured by these techniques have been consistent with literature, they have not been validated against other methods. In this study we investigated the cross-validation of physiological MRI techniques against oxygen-15 positron emission tomography (O-15 PET), and near infrared spectroscopy (NIRS). The primary measure of interest is the oxygen extraction fraction (OEF), however measurements of blood flow (CBF), blood volume (CBV) and oxygen consumption ($CMRO_2$) were also compared between MRI and PET.

Methods & Results 15 healthy subjects (12♂, 36±10yrs) were recruited; the use of PET restricted female subjects to those incapable of conception. Steady-state triple oxygen O-15 PET scanning was performed on a GE Advance PET scanner.[2] Arterial blood sampling during PET provided PaO_2, SaO_2 and Hct. NIRS tissue saturation (StO_2) data was collected simultaneously using a 2-channel Hamamatsu NIRO 200, with one sensor placed on either side of the forehead. NIRS OEF was calculated from StO_2, SaO_2 and an assumed arterial/venous blood volume ratio of 30/70. Dual-gas calibrated MRI was performed on a 3T Siemens Verio with a 32-channel head coil, using a single PLD double-excitation (dexi) pCASL sequence.[3] Respiratory gasses (air, FiO_2~0.5 (2x3mins), $FiCO_2$~0.05 (2x2mins)) were delivered and measured via a 2-tube nasal cannula. CBF was measured with a multi-PLD pCASL sequence. MRI analysis was done on a voxelwise basis. A grey matter mask was defined from a high-resolution FAST mask and registered back into native spaces. No additional smoothing was carried out. Correlations between grey matter means for each subject are shown in Fig. 1 (one outlier was removed from the PET CBF set, and 2 removed from the MRI OEF set). Maps from 2 subjects are shown in Fig. 2.

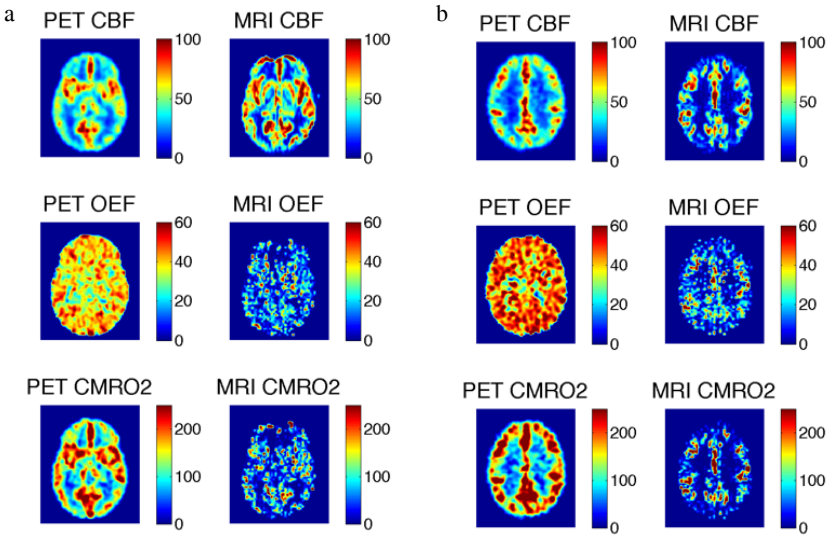

Fig. 2. PET and MRI maps of CBF, OEF and CMRO2 from 2 representative subjects (a and b) showing a single slice for each subject.

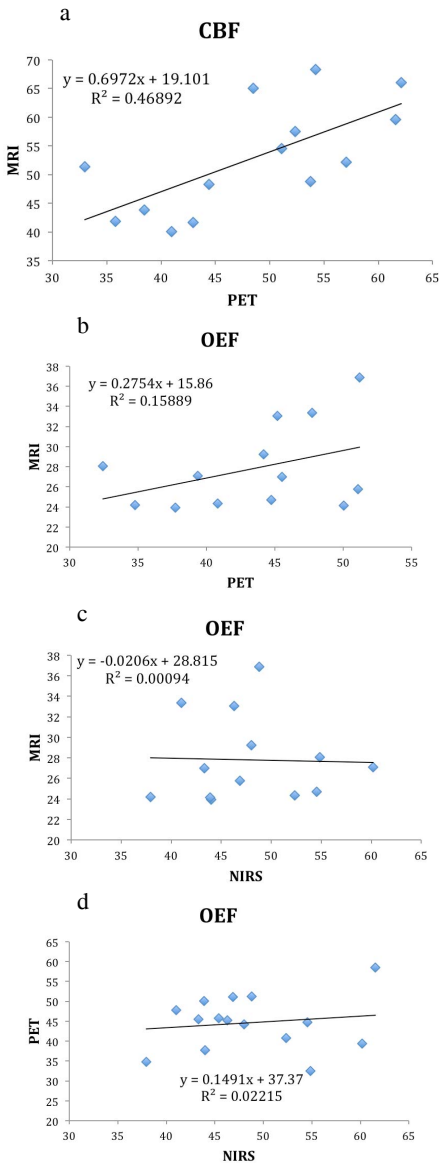

Fig. 1. Mean GM values for each subject.
a: CBF MRI v. PET, b: OEF MRI v. PET,
c: OEF MRI v. NIRS, d: OEF PET v. NIRS.

Discussion & Conclusions There was a degree of correlation between pCASL MRI and PET CBF (Fig. 1a), as has been shown previously.[4] However, there was poor correlation between the MRI OEF and the PET OEF, and the MRI OEF was much lower than PET (Fig. 1b & 2), albeit with the MRI OEF maps having much less spatial variability (Fig. 2a&b). There is at least some correlation between MRI and PET, although it is far from 1:1, whereas NIRS had no correlation with either of the other 2 modalities (Fig. 1c&d). MRI measures of OEF (~0.35)[5] have typically been lower than PET (~0.45).[2] As pCASL produces little or no white matter (WM) signal, the MRI OEF in WM cannot be trusted. PET uses a large degree of spatial smoothing, as can be seen from the maps, which will affect the mean values. The 3 modalities are measuring different correlates of OEF, and using different models to link measured signals with the physiology, each with their own SNR characteristics. It is possible that the inter-session variability (due to low SNR) was actually greater than true inter-subject variation, and that the range of underlying OEFs was too small to observe any trends. Background suppression has recently been shown to enhance pCASL SNR,[6] but was unfortunately not used for this experiment. Additionally, no end-tidal CO_2 trace was available due to restrictions of nasal cannula sampling. This resulted in not being able to use these traces as functional regressors, reducing the quality of fits during analysis. It is hoped that implementing background suppression and using a facemask for gas delivery would boost the pCASL SNR during hypercapnia and thus improve the reliability of MRI OEF values in future work.

References

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