# Correlation of MRI-OEF and PET-OEF neuroimaging data for study of hypoxia in brain tumors

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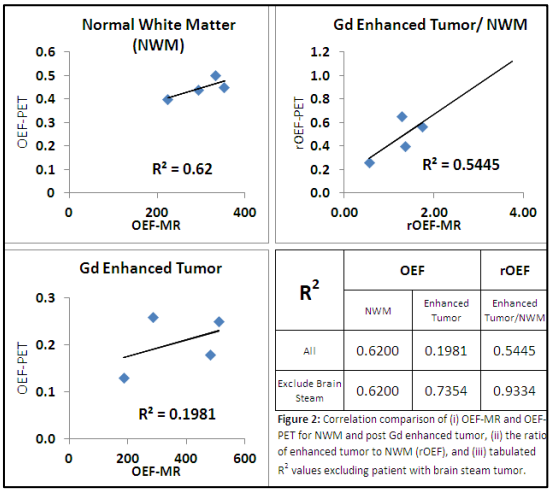
**Introduction:** Cerebral tissue hypoxia, defined as an imbalance between the supply and consumption of oxygen has been associated with sensitivity of tumors to radiation therapy, mutation frequency, altered gene expression of involved cell, and it can potentially impact treatment outcome and patient survival. The only validated *in vivo* noninvasive technique currently available to directly measure oxygen extraction fraction (OEF) in the brain is a $^{15}O$ positron emission tomography (PET); however, little data is available on brain tumor OEF in patient populations. Similarly non-contrast MR techniques[1, 2] can non-invasively provide quantitative measurements of tissue hemodynamics, such as the regional cerebral OEF measurement. These methods have tremendous potential and may offer new insight into the underlying physiology of brain tumors and their response to therapy without requiring radiation or injected contrast. Preliminary results of the MR procedure for measuring brain and brain tumoral OEF are presented and compared with the results obtain using $^{15}O$-PET.

**Methods:** 5 patients (4 M) with combination of unresected metastatic (breast, n=1) and primary brain tumors (Glioblastoma, n =4) were recruited for the study. MR sequences were performed at 1.5 T Siemens scanner. The imaging protocol included standard pre and post contrast clinical anatomic images with the advanced imaging sequence of dynamic susceptibility contrast (DSC). Research imaging sequences included OEF-MR; a two-dimensional multi-echo gradient spin echo sequence was used with the following imaging parameters: number of slices=19, voxel size=3.6X3.6X5, TR=3000 ms, TE1=78 ms, TE2=114.4 ms, 4 head coil element, resolution=64x64, echo spacing=0.49 ms, measurements=150, and scanning time= 7:36 min. A system shimming was carefully employed prior to the imaging experiments. Concurrent with the MR acquisition, subjects undergo PET scanning using the Siemens Biograph 40 PET/CT. During the PET imaging, at 2 different times, subjects were undergone a set of 3 scans where they are asked to either inhale air which contains 40-75 mCi radioactive carbon monoxide ($C^{15}O$), inhale air which contains 40-75 mCi radioactive oxygen ($^{15}O_2$), or receive an injection of 25-50 mCi radioactive water ($H_2{}^{15}O$). Both MR and PET data were post-processed off line and registered to the anatomic T1 pre and post contrast images. Regions of interest were drawn based upon contrast-enhancing tumor areas, non-enhancing T2-hyperintense areas of edema adjacent to tumor, and contra-lateral normal white matter (NWM). Ratios of rOEF were obtained for lesions compared to normal tissue.




| $R^2$ | OEF | | rOEF |
|---|---|---|---|
| | NWM | Enhanced Tumor | Enhanced Tumor/NWM |
| All | 0.6200 | 0.1981 | 0.5445 |
| Exclude Brain Steam | 0.6200 | 0.7354 | 0.9334 |

**Figure 2:** Correlation comparison of (i) OEF-MR and OEF-PET for NWM and post Gd enhanced tumor, (ii) the ratio of enhanced tumor to NWM (rOEF), and (iii) tabulated $R^2$ values excluding patient with brain steam tumor.

**Results:** Complete set of OEF-MR, DSC-MR, and $^{15}O$ PET were obtained in 4 patients. Sample of the images are shown in Figure 1. Although both OEF-MR and OEF-PET indicate abnormality in the tumor area (enhanced T1 post contrast), there is discrepancy between the two methods. Plots of OEF and rOEF for selected regions of NWM and Gd enhanced tumor using MR and $^{15}O$ PET procedures are given in Figure 2. A high correlation between OEF-MR and OEF-PET results is obtained ($R^2$ = 0.620) for NWM while the correlation for Gd enhanced tumor is low ($R^2$=0.1981). However, the ratio of the enhanced tumor to NWM (rOEF) show good correlation ($R^2$=0.5445), and the corresponding correlations increase by eliminating the patient with steam brain tumor ($R^2$=0.7354 & $R^2$=0.9334), respectively.

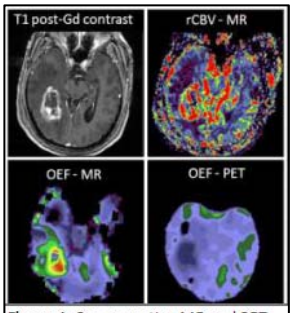



**Figure 1:** Pre-operative MR and PET scans in a 56Y old man with GBM tumors. Post contrast T1 images reveal an enhancing lesion, rCBV indicate a high value. OEF-MR shows high value and OEF-PET has a low value in the enhanced area

**Conclusions:** Although comparison of the measured OEF for primary and metastatic brain tumors obtained by non-contrast MR and noninvasive $^{15}O$-PET procedures is promising (e.g., good correlation between OEF-MR and OEF-PET, and both method show abnormality in tumor area), however, some observed discrepancy between the two methods will need further investigation. This is an ongoing project and more data are being collected

**References** [1]*He and Yablonskiy (2007). "Quantitative BOLD: mapping of human cerebral deoxygenated blood volume and oxygen extraction fraction: default state." Magn Reson Med*

[2]An and Lin (2000) Quantitative measurements of cerebral blood oxygen saturation using magnetic resonance imaging. *J. Cereb. Blood*, *Flow Metab*;