Improved FDG kinetic Analysis in Brain Tumors Through Simultaneous MR/PET Acquisition

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Target audience: Physicists, neuroscientists and radiologists interested in quantitative MR/PET brain imaging

Purpose: Pharmacokinetic modeling of dynamically acquired images permits extraction of physiological and functional information useful for grading brain tumors. Tracer kinetics can be calculated with the known (arterial) input as a function of time (AIF) that can be obtained either from arterial blood sampling, which is invasive, time-consuming, and clinically impractical, or as an image derived input function (IDIF) from a region of interest (ROI). The first phase distribution within the blood system is expected to be similar for Gadolinium and ^{18}F-FDG because they are both low-molecular weight compounds. Therefore, high-resolution MR data can be used to overcome the low spatial resolution of PET images, which leads to significant bias when estimating the IDIF. The goal of the study is to investigate the use of a higher-resolution, MR-derived AIF for improving tracer kinetic parameters estimates from human brain tumor patients during dynamic FDG injections without direct arterial sampling.

Methods: A phantom scan was performed to compare the time courses of the actual tracer distribution, as measured directly using a dedicated PET detector (Twilite, Swisstrace, Zurich) external to the scanner, to that measured from the PET images. For this experiment, a bolus of ^{18}F-FDG was quickly injected into a tubing system connected to a brain phantom pre-filled with water and list mode data was acquired dynamically. The activity in the solution was also measured directly at the input to the phantom by continuously taking small volumes of fluid and measuring the corresponding activity using a gamma counter. PET images were reconstructed into 5 second bins and the AIF determined from the signal intensity of a ROI placed at the same location where the samples were taken. Figure 1A presents a comparison between these measurements and illustrates that the partial volume effect is significant when the AIF is measured from PET images alone. For the human experiments, a total of 9 brain tumor patients were concurrently and dynamically scanned with PET and MR using list mode data and radial, compressed-sensing aided dynamic contrast enhanced (DCE) MRI; respectively. PET images were reconstructed into 5 seconds bins for the initial uptake phase while MRI DCE data were reconstructed using a non-uniform fast Fourier transform (NUFFT), motion corrected and re-registered to the PET volumes. PET and MR AIFs were measured from a ROI in the carotid artery. The MR-derived AIF was then normalized and scaled to peak activity measured from the PET AIF (figure 1, B). The Sokoloff-Model[1] was applied to calculate k_1 using the MR and PET-based AIFs. K_2 and k_3 were then calculated using these k_1 values with the PET-based AIFs and tracer kinetic constants were compared.

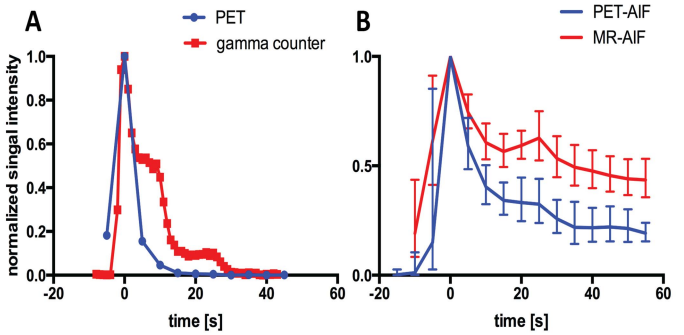

Figure 1. Input functions from (**A**) Phantom scan. (**B**) Mean and 95% confidence interval of PET- and MR- derived AIFs of 9 patients. Note: Shape of MR-derived AIF (**B**) mimics shape of curve from phantom scan in relation to PET function (**A**).

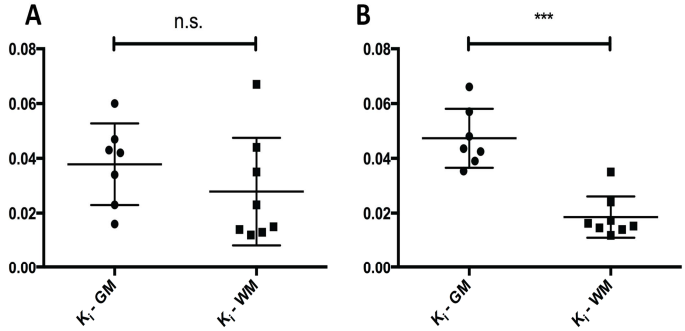

Figure 2. Ki values of grey and white matter obtained from (**A**) PET-AIF only and (**B**) combined PET- and MR-AIF. Using the combined AIF approach enables better discrimination between grey and white matter.

Results and discussion: PET based AIF's consistently underestimated FDG activity for the phantom and patients scans. As reported elsewhere[2], non-linear fit of the dynamic PET data using PET-based AIF's was biased due to excessive partial volume effects in the images. Estimation of k_1 using the MR-derived AIF led to improved accuracy for the tracer kinetic parameters. The error in the distribution of values for K_i of grey matter and white matter was significantly reduced when the MR-based AIF was used and, moreover, a statistically significant difference between the gray and white matter was detected.

Conclusion: Our results suggest concurrent dynamic MR/PET acquisition could provide a means to obtain more accurate estimates of tracer kinetic parameters during routine clinical examinations using FDG in brain tumor patients.

Funding: NIH 2R01CA111996-06A1. **References:** [1] Sokoloff et al., J Neurochm 28(5), 297-918, 1977, [2] Huisman et al., EJNMMI Res., 2(1):63, 201