Estimation of a PET AIF using DSC MRI

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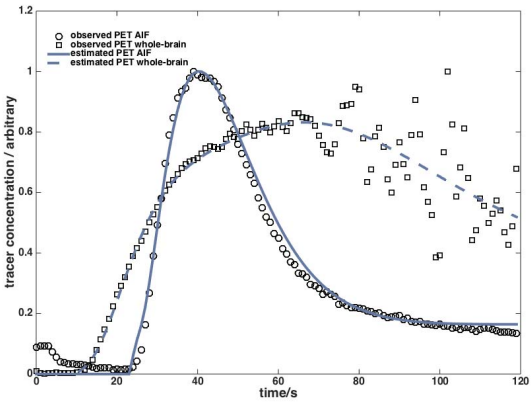
TARGET AUDIENCE – Researchers interested in measuring brain perfusion using PET/MRI scanners

PURPOSE – Quantitative perfusion studies by PET can be limited by difficulties obtaining reliable sampling using arterial lines, which can be painful to patients, and significantly complicate PET experiments. Similarly, quantitative MRI perfusion studies have been challenged by variability of biology and instrumentation: universal scaling coefficients for quantitation have been elusive. The recent introduction of PET/MRI machines has opened the opportunity for acquiring simultaneous perfusion information using both methods and improving the quantitation of both using this additional information.

METHODS – Analysis was performed on a heterogeneous cohort of 19 patients with clinically significant cerebrovascular disease. This was a smaller group with complete PET and MRI data taken from a larger study in which both whole brain $H_2[^{15}O]$ perfusion PET scans with an arterial line, and DSC perfusion MRI were performed on the same day.[1] From the DSC data we obtain an estimate for the whole brain AIF using previously published methods.[2] The most promising model for the MRI AIF comprised a gamma-variate arterial input functions (AIF) to describe bolus-passage of an intravascular MRI contrast agent.[2] In order to reproduce the PET AIF these MRI AIFs were convolved with an analytical residue function that models the extravascular transport of positron-emitting $H_2[^{15}O]$. In order to estimate the whole brain PET signal a second convolution was performed with a separate residue function that models transport of $H_2[^{15}O]$ throughout brain parenchyma.[3] A comparison was performed between the MRI derived result and the true whole-brain $H_2[^{15}O]$ scans from the same cohort. Parameter estimation using this perfusion model was implemented with Markov-chain Monte Carlo, Metropolis-Hastings sampling and simulated annealing to determine posterior probabilities.[2] The Bayesian approach provided estimates for both a PET AIF and the whole-brain PET. The estimated PET AIFs were compared to independently observed tracer time-curves from the patient cohort. As the amplitude of PET AIFs depend on details of radial artery cannulation, estimated and observed PET AIFs were compared after being normalized by their maxima.

RESULTS – Representative results for a single patient are demonstrated in figure 1. Seventeen additional patient-cases yielded similar results. One patient case failed to yield parameter estimates. Biological variability was evident in most model parameters with coefficients of variation across patients of the order of unity.

Figure 1. Representative results from a single moyamoya patient. The observed whole-brain PET in-flow (squares) and observed MRI bolus-tracking data (not shown) are the sources of information for the analysis. A multiple convolution model was used. Dashed-line: best fit of model and parameters to the PET in-flow. Solid-line: best estimate of the underlying PET AIF is shown. The estimated PET AIF is compared to observed PET tracer sampling from radial artery cannulation (circles).



DISCUSSION – The results of this research potentially have significance for all quantitative PET perfusion studies for which using cannulated arterial sampling may be difficult or impractical. Incorporating information from MRI bolus-tracking studies in the same patient that has had a PET perfusion study has yielded results that are robust across 18 of 19 patients with clinically significant cerebrovascular disease. This could potentially improve quantification of PET perfusion studies without an arterial line and could be especially useful in the new generation of PET/MRI scanners. The biological variability of model parameters may have significance for research in quantitative MR perfusion.

CONCLUSION – This research describes a novel model of cerebral perfusion that incorporates coupled information from PET water studies as well as MRI bolus-tracking. The model predicts PET AIFs that have excellent agreement with independently sampled PET tracer from radial artery cannulation and could be a useful adjunct to perfusion studies on the new generation of PET/MRI scanners.

REFERENCES

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