Estimation of Hemodynamic Impairment using Dynamic Susceptibility Contrast Perfusion Imaging

J. J. Lee[1], C. P. Derdeyn[1], W. J. Powers[1], T. O. Videen[1], J. Markham[1], A. Z. Snyder[1], G. L. Bretthorst[1], and J. S. Shimony[1]
[1]Washington University School of Medicine, Saint Louis, MO, United States

INTRODUCTION: The Hemodynamic Impairment Index (HII) correlates strongly with the likelihood for the occurrence of a stroke and is therefore of great clinical interest [1]. The index has been defined using PET criteria, but has not been evaluated using MRI. We use a novel dynamic susceptibility contrast (DSC) MRI method to estimate tissue perfusion that expands on traditional methods by estimating a local AIF (LAIF) for each pixel in the image [2,3]. This model overcomes several drawbacks of traditional methods and provides estimation of additional parameters that may be of clinical importance. The parameters appearing in this model are estimated using Bayesian probability theory and Markov chain Monte Carlo simulations to sample the joint posterior probability. Preliminary results using this model compare favorably to PET results and to traditional MR methods in a population of patients with carotid occlusion and variable amounts of hemodynamic impairment as measured by PET criteria. In the current project we use the LAIF method to estimate the HII using MRI criteria and compare these to the HII as estimated by PET.

METHODS: As part of the St. Louis Carotid Occlusion Study perfusion measurements were performed in 19 patients using both PET and DSC MR within the same day. Written informed consent was obtained on all subjects in accordance with guidelines of the local institutional review board. Tracer kinetic perfusion models derive the following relationship between the tissue concentration (C_T), cerebral blood flow (CBF), pixel impulse residue curve (R(t)), and the AIF (C_A): $C_T(t) = CBF \cdot R(t) \otimes C_A(t)$. The residue curve was approximated as an exponential with a mean transit time (MTT) decay constant: $R(t) = \exp[-(t - t_0)/MTT]$. The AIF was modeled as having three distinct components: $C_A(t) = aGV(t, t_0) + bGV(t, t_1) + c$. The main contrast bolus was modeled as a gamma variate function (GV) arriving at t_0. The recirculation peak was also modeled using a GV arriving at a later time t_1. The steady state component was modeled as a constant. These expressions were substituted into the first equation and the convolution was performed analytically. The posterior probabilities for the model parameters were computed for each pixel given the time series data using Bayesian probability theory and Metropolis-Hastings Markov chain Monte Carlo simulation with simulated annealing. Regions of interest (ROI) were selected in both the ipsil- and contra-lateral sides of the brain to evaluate the degree of asymmetry. The HII in PET imaging was assessed from the degree of asymmetry in the mean transit time (MTT) and cerebral blood volume (CBV) between the side of the carotid occlusion and the normal side [4]. Similar estimation was performed using the MRI data.

RESULTS: The figures demonstrate the strong correlation between the degree of asymmetry as determined by PET imaging and that determined by MRI criteria. The horizontal axis represents the left over right (L/R) ratio of PET MTT and CBV. The vertical axis represents the L/R ratio MRI MTT and CBV in additional to the L/R ratio of the alpha and beta parameters which describe the estimated LAIF.

CONCLUSION: The HII can be accurately estimated using MRI data and has a strong correspondence with the HII estimated using PET criteria which has been shown to be clinically valuable [1].

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REFERENCES:

[1] Grubb RL, et al. JAMA 280(12):1055-1060, 1998. [2] Shimony JS, et al. Bayesian Inference and Maximum Entropy Methods in Science and Engineering 803:535-542 (2005). [3] Shimony JS, et al. Proc. Intl. Soc. Mag. Reson. Med. 14:3564 (2006). [4] Mukherjee P, et al. AJNR 24:862-871 (2003).