Imaging microvascular flow distributions using residue function shape characteristics

K. Mouridsen[1], S. Kiebel[2], N. Hjort[1], L. Østergaard[1]

[1]Center for Functionally Integrative Neuroscience, Aarhus University Hospital, Aarhus, Denmark, [2]The Wellcome Department of Imaging Neuroscience, Institute of Neurology, London, United Kingdom

Introduction

DSC-MRI has proven very useful for deriving haemodynamic parameters such as CBF, CBV and MTT. These quantities are important diagnostic tools, *e.g,*. in acute stroke, where they are used to identify ischemic regions. CBF may be computed using singular value decomposition (SVD) [1], but important information about the capillary flow patterns contained in the residue function is difficult to retrieve and quantify. In this study we use a parametric vascular model [2] to estimate perfusion parameters as well as residue function shape characteristics related to microvascular flow. It has been hypothesized that microvascular flow patterns may be crucial to assess tissue viability in ischemia [3].

Theory

Based on the statistical parametric model for the microvasculature presented in [2] we parametrize the transport function *h(t)* representing the distribution of capillary transit times by the gamma density function $h(t) = \beta^{-\lambda}\Gamma(\lambda)^{-1}t^{\lambda-1}e^{-t/\beta}$ with shape parameter λ and scale β. The residue function (RF) *R(t)*describes the fraction of particles retained in the vasculature at *t and,* is found by integrating *h(t).* These RFs exhibit a variety of shapes from exponential ($\lambda = 1$) to approximately box-car (λ large), see Fig. 1. These parameters together with CBF may be estimated using a Bayesian system identification approach [2,4] where the concentration time curve (CTC) $C(t) \propto CBF\int_0^t C_a(\tau)R(t-\tau)d\tau$ is fitted to the observed CTC for a given arterial input function (AIF) $C_a(t)$.

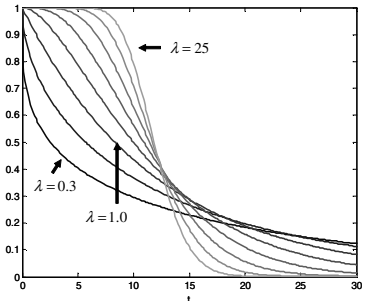

Figure 1 Residue functions for different values of the shape parameter (β=*MTT*/λ)

Materials and methods

To assess the ability of the algorithm to estimate the shape parameter of the residue function we simulated CTCs using residue functions with $\lambda = 1$ to $\lambda = 25$ for CBF=20ml/100g/min, CBV=4% and SNR=100. Simulations were repeated with an added delay of 5s between the AIF and the CTC. We also analyzed data from a 63 y.o. female with an acute right-sided MCA occlusion (3.0 T gradient echo EPI, TR/TE=1500/45 msec).

Results

Fig. 2 shows good agreement between the simulated and estimated values of the shape parameter. Critically, these estimates are unaffected by delay. The perfusion maps of the stroke patient (Fig. 3) show reduced CBF and prolonged MTT in the MCA territory. The maps of the residue function parameters indicate that the residue function in the core of the infarct are box-car while the penumbra residue functions are close to exponential with increased dispersion relative to the contralateral side.

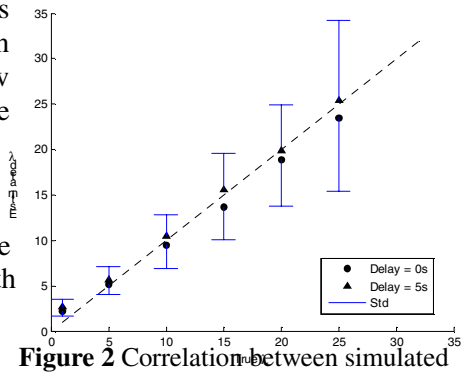

Figure 2 Correlation between simulated and estimated values of shape parameter λ.

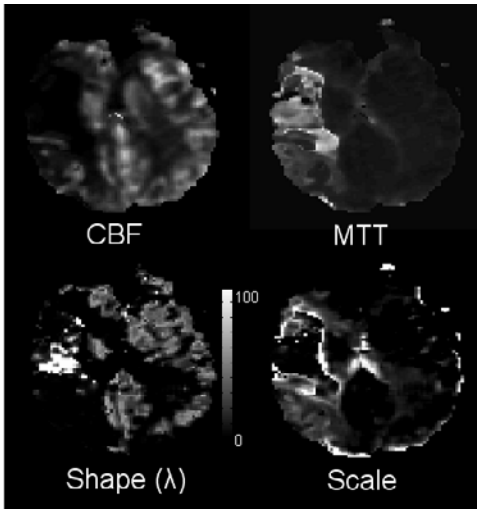

Figure 3 Perfusion maps and images of residue function shape characteristics for a patient with MCA occlusion.

Discussion

Fig. 3 indicates that different microvascular flow profiles may underlie the perfusion lesions observed on CBF and MTT maps. For example, subregions of altered flow characteristics (exponential RFs with high flow components as well as more 'plug' like flow) not delineated on CBF and MTT maps, were observed. We speculate the present approach may allow the study of microvascular flow phenomena such as vasoparalysis, capillary dysfunction due to cell adhesion and neovascularization.

References: [1] Østergaard et. al, MRM 1996. [2] Mouridsen et. al, Proc ISMRM 2005. [3] Østergaard et. al, Stroke 2000. [4] Friston et.al, NeuroImage 2003.