Clinical utility of parametric perfusion estimates in prediction of final outcome in acute stroke

K. Mouridsen[1], K. Y. Jonsdottir[1], S. Jespersen[1], and L. Ostergaard[1]
[1]Department of Neuroradiology, Aarhus University Hospital, Aarhus, Denmark

Introduction

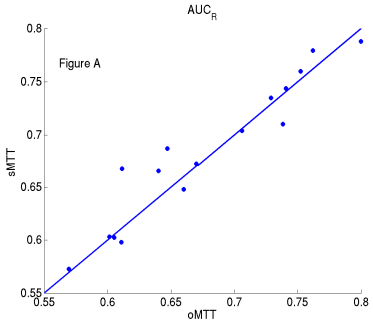
DSC-MRI parameters such as cerebral blood flow (CBF) and mean transit time (MTT) are important diagnostic maps, *e.g.* in acute stroke where they are used to identify ischemic regions. Non-parametric methods such as standard singular value decomposition (sSVD) [1] or the timing-insensitive, block-circulant variant (oSVD) [2], are commonly used to estimate perfusion parameters, but these methods produce highly fluctuating residue functions and high flow components are biased low. Recently, a parametric Bayesian approach, based on a physiological model of the microvasculature, has been shown to produce less biased flow estimates and produce smooth and monotonically decreasing residue functions in agreement with physiology [3]. In addition, the oxygen extraction fraction (OEF) can be calculated based on the estimated capillary flow distribution [4]. However, the clinical utility of perfusion estimates depends on their ability to correctly predict final infarct size. Here we use voxel-wise predictive algorithms to compare the predictive strength of sSVD, oSVD and parametric perfusion parameters.

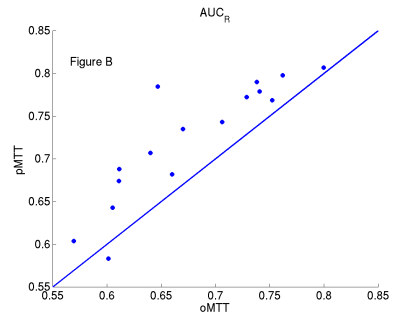
Materials and methods

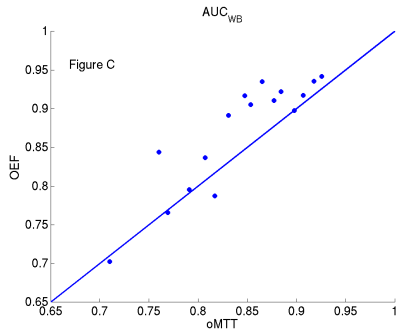
Standard perfusion and diffusion weighted images were acquired for n=28 patients with acute stroke. All patients were treated with rtPA and a follow-up T2 scan was performed after 3 months. Final infarcts were outlined by a neuroradiologist. N=16 patients with final infarcts larger than 5ml were included in the analyses. MTT was calculated using sSVD, oSVD and the parametric model (denoted sMTT, oMTT and pMTT). In addition, OEF was calculated based on the parametric model as in [4]. To quantify the predictive strength of each deconvolution approach, a logistic regression model was trained for each perfusion parameter separately using jack-knifing [5]. DWI and T2 were also included in each model. The training set was balanced and consisted of voxels in the outcome lesion and healthy voxels from both the contra-lateral hemisphere and the diffusion/perfusion mismatch region. Predictive performance was measured using the area under the receiver operating characteristics curve (AUC). This was evaluated in the region corresponding to prolonged MTT, such that the calculated AUC (AUC_R) reflects the ability to separate infarcting from non-infarcting voxels in the most critical region. (AUC_R) is taken as a conservative estimate of overall model performance. AUC was also computed using all brain voxels, which is more common (AUC_V).

Results

No difference in predictive performance was found between oMTT and sMTT (Wilcoxon, p=0.33). For oMTT median AUC_R=0.68, inter quartile range (IQR) [0.61; 0.74] and for sMTT median AUC_R=0.68, IQR [0.63; 0.74]. Figure A further indicates the similarity between oMTT and sMTT. In contrast, pMTT yielded significantly (Wilcoxon, p<0.001) higher performance (median AUC_R=0.74, IQR [0.68; 0.78]) compared to oMTT. Moreover, as seen in Figure B, performance of pMTT was higher in 15 out of 16 patients (Exact binomial test, p<0.001). Similar results are observed when AUC is calculated using all brain voxels, where pMTT also leads to significantly increased performance compared to oMTT (Wilcoxon, p=0.01). OEF (median AUC_V=0.90, IQR [0.82; 0.92]) leads to significantly better overall performance than oMTT (AUC_V=0.85, IQR [0.80; 0.89]), Wilcoxon, p<0.01 (see Figure C), although the improvement in AUC_R was not significant (p=0.15).







Conclusion

Mean transit time calculated based on the Bayesian parametric model leads to significantly improved prediction of final infarct size using both performance measures (AUC_R, AUC_V) compared to the SVD methods. Moreover, the best (AUC_V) performance was observed using OEF. In contrast, no significant difference was found between sSVD and oSVD estimates using either performance measure. This suggests an improved clinical utility of perfusion estimates based on the vascular model [3] compared to SVD methods.

References

[1] Østergaard et. al, MRM 1996. [2] Wu et al, MRM 2003. [3] Mouridsen et al, Neuroimage 2006. [4] Jespersen et al, ISMRM Workshop on Cerebral Perfusion and Brain Function 2007. [5] Wu et al, Stroke 2001.