Does local AIF improve prediciton of final infarct?

S. Christensen[1,2], F. Calamante[3], O. Wu[4], T. Götz[5], J. Fiehler[6], J. Rother[5], T. Kucinski[6], L. Ostergaard[2], P. Desmond[1], and S. Davis[7]

[1]Department of Radiology, University of Melbourne, Parkville, Victoria, Australia, [2]CFIN, University of Aarhus, Aarhus, Denmark, [3]Brain Research Institute, Melbourne, Victoria, Australia, [4]Athinoula A. Martinos Center, Massachusetts General Hospital, Boston, Massachusetts, United States, [5]Dept. of Neurology, University Medical Center Hamburg-Eppendorf, Hamburg, Germany, [6]Dept. of Neuroradiology, University Medical Center Hamburg-Eppendorf, Hamburg, Germany, [7]Dept. of Neurology, University of Melbourne, Parkville, Victoria, Australia

Introduction:

It has been speculated that the diagnostic accuracy of Perfusion Weighted Imaging (PWI) may be improved by utilizing local arterial input functions (AIF) representing the delayed and dispersed tracer supply to peri-infarct tissue [1]. We tested the hypothesis that multiple local AIFs provide PWI maps with greater diagnostic accuracy than traditional PWI maps based on a single (global) AIF.

Methods:

104 patients with acute Diffusion Weighted Imaging (DWI)/PWI within 6 hours of stroke onset, and T2/DWI-imaging on follow up (F/U) (>5 days), were retrospectively analyzed. Perfusion maps from the 'conventional' AIF selection method (contra-lateral 'global' AIF by manual selection) and two local AIF methods were calculated. Local AIF method 1 was an implementation of a fully automated method described by Lorenz et al. [2] which uses various heuristics to determine appropriate arterial voxels in the dataset and then uses smoothing operators to interpolate local arterial input functions. Local AIF method 2 was a method based on previous work [3] where functional vascular territories are defined by means of the concentration time curves and this information is used to detect AIFs and determine the segments of tissue supplied by a given AIF.

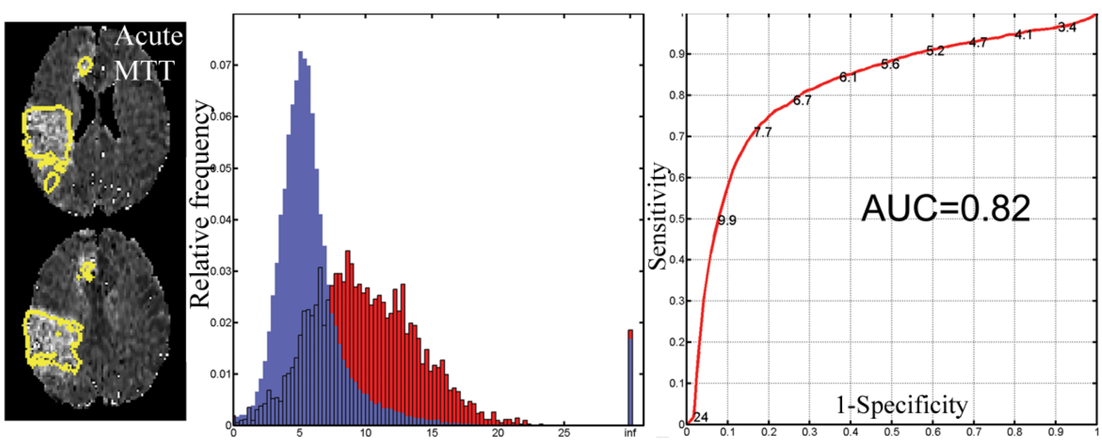
Maps of Cerebral Blood Flow (CBF), Mean Transit Time (MTT) and time to peak of the residue function (Tmax) were generated for all three methods using circular SVD [4]. F/U ROIs were delineated on the day 5 DWI and B0 images and the union of the two was used as the infarct ROI mask. Receiver Operating Characteristics (ROC) analysis was performed on the acute PWI maps using the F/U infarct ROI as infarct/no-infarct classifier. In this way, each map was summarized by its area under the ROC curve (AUC), essentially summarizing with a scalar value the predictive information in a given map. The performance of each local AIF selection method was compared for each modality (MTT, CBF and Tmax) to the conventional contra-lateral AIF selection by a paired sign test.

Results:

For MTT maps, the AUCs were significantly higher for conventional contra-lateral AIF selection as compared to the local AIF methods: Median AUC difference was 0.01 (local method 1) and 0.02 (local method 2) with P values both <0.001.For CBF maps the local methods were also significantly outperformed with a median difference of 0.01 for both local methods (P<0.001). Delay maps were even less favorable when generated by the two local AIF methods; median differences were here 0.03 (local method 1) and 0.02 (local method 2) with P<0.001 in both cases. For all above comparisons contra-lateral AIF selection yielded higher AUCs in more than 65% of patients. Focusing on conventional contra-lateral AIF selection, MTT was more predictive of infarction than CBF (P<0.001), median difference of 0.04. Tmax maps outperformed MTT maps (P=0.03) with a median difference of 0.01. Median AUC for Tmax was 0.77 (quartiles 0.71-0.82).

Discussion/conclusion:

This study is, to the best of our knowledge, the largest comparison between local AIF techniques and conventional AIF techniques so far. Although differences are marginal (AUC differences of approx. 0.01) and barely noticeable to the eye, the local AIF techniques significantly decreased the predictive value of the perfusion maps in these patients. The fact that Tmax becomes less predictive using local techniques is not surprising since local AIF techniques essentially remove the delay that Tmax reflects. For MTT however, it is expected that the maps would be more accurate reflections of tissue perfusion by accounting for AIF dispersion. This was not supported by the data. We speculate that delay and dispersion might have predictive value and should not be disregarded but rather decoupled from perfusion estimates and interpreted in conjunction. The frequent use of the heavily delay and dispersion weighted Tmax parameter as a clinically meaningful tissue outcome predictor in stroke studies (eg. DEFUSE and EPITHET) supports this notion. Both local AIF techniques are automated and unsupervised and tissue concentration time curves are selected based on the curve properties without anatomical reference. As such, the possibility exist that both non-arterial and distorted curves are selected. It is an underlying assumption for local techniques that the signal curve from distal arteries, likely to be partial-volumed, reflects the true AIF inside the vessel. This assumption remains unproven and has indeed been challenged multiple times [5,6]. We are currently working on a sub-analysis of the patient population to investigate whether the performance of the local AIF methods is influenced by re-perfusion. In conclusion, the findings raise questions as to the feasibility of extracting valid AIF curves from smaller arteries as well as to the predictive role of delay and dispersion in acute stroke.



Patient example of methodology:
Left: Shows acute MTT maps, yellow outline is the co-registered follow up mask. **Middle:** The histogram shows distribution of MTT values in the F/U infarct (red) and outside (blue). **Right:** ROC curve with area 0.82.
The AUC measure inherently reflects how well the acute PWI map illustrates the F/U lesion as a well delineated hyper-intense region.

References: [1] Calamante, et al. MRM 2000;44(3). [2] Lorenz, et al. J Magn Reson Imaging. 2006 Nov;24(5). [3] Christensen et. al Proc. ISMRM 2007 #591. [4] Wu, O.et al. MRM 2003;50(1). [5] Van Osch et al. J Magn Reson Imaging. 2005 Dec;22(6). [6] Duhamel G., et al. Magn Reson Med. 2006 Mar;55(3).