ACUTE MIDDLE CEREBRAL ARTERY STROKE - COMPARISON OF HAEMODYNAMIC TIMING PROPERTIES ASSESSED BY DYNAMIC CONTRAST-ENHANCED PERFUSION MEASUREMENT AND ARTERIAL SPIN LABELING

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Introduction

Dynamic Susceptibility Contrast (DSC) imaging and Arterial Spin Labeling (ASL) are two different approaches to assess haemodynamic parameters. The two techniques yield different basic timing properties – e. g. time to peak (TTP) in DSC and bolus arrival time (BAT) in ASL - which give different measures of the same underlying haemodynamic mechanisms. While the temporal resolution of DSC is limited to 1-2 seconds, ASL time series can in principle be acquired in arbitrarily small intervals.

TTP maps derived from DSC data are clinically attractive as they are very sensitive to delay of the contrast bolus arrival indicating changes in tissue perfusion. Theoretically higher temporal resolution might classify different degrees of severity of hemodynamic compromise in more detail and could overcome some of the uncertainties associated with DSC analysis.

In order to clarify this issue we studied acute stroke patients with middle cerebral artery stroke and areas of reduced tissue perfusion useful for ROI analysis of different degrees of severity of tissue perfusion reduction. DSC with a temporal resolution of 1.5 sec and ASL with a resolution of 0.25 s were compared for seven patients (two male, five female, mean age 71 yrs).

Materials and methods

A clinical 1.5 T scanner (Magnetom Sonata, Siemens, Erlangen, Germany) was used for imaging. Maximum gradient strength was 40 mT/m with a slew rate of 200 mT/m/ms. A standard MRI protocol included time-of-flight angiography (TOF-MRA), diffusion-weighted imaging (DWI) and DSC-MRI. TTP maps were derived by deconvolution with an automatically determined arterial input function [1].

ASL time series were obtained using a single-shot 3D-GRASE read-out module [2]. Multiple TI ranging from 250 ms to 2500 ms were measured in 10 time steps, the acquisition time was 7:00 min. Microvascular perfusion (CBF) and BAT maps were extracted from the time series using nonlinear least-square optimization.

Results

TTP and BAT maps for all patients differentiated normal from reduced perfusion in all cases (e.g. Fig1).

In a direct comparison, BAT and TTP values showed a linear relationship (Fig2) indicating that the same underlying haemodynamics have been measured. In watershed areas (e.g. ROI 2, 4, 8) the BAT map shows significant delay (≈500ms) whereas in TTP maps in some cases the delay cannot be resolved (e.g. outliers ROI 2 and 8).

A closer look into an area of acute ischemic tissue reveals that BAT gives reliable measures of inflow delay. In Fig. 3, ROI 1 and 2 show significant delay while ROI 3 and 4 lie in a hypoperfused area (as can be seen on the perfusion map) and therefore yield low BAT values. It can be seen from Tab. 1 that the standard deviation of corresponding TTP values is very high and DSC therefore cannot yield reliable measures of inflow time on a small spatial scale. This is due to the fact that there is a high fluctuation of delay time values between pixels.

For areas in black on the BAT map (e.g. Fig.1: between ROI 6 and 7) no BAT values could be derived due to low SNR. In ASL, not only low perfusion but also long inflow times lead to low SNR because of T1 decay. This is the case especially for areas of CSF and white matter and e.g. for the infarct core.

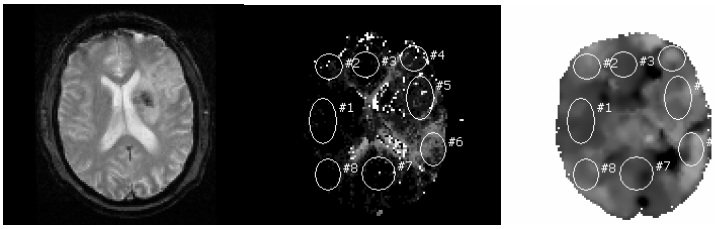

Fig.1: From left to right: T2 weighted image, TTP and BAT maps for one selected patient; both maps show significant delays on the left hemisphere (higher pixel values, in ms).

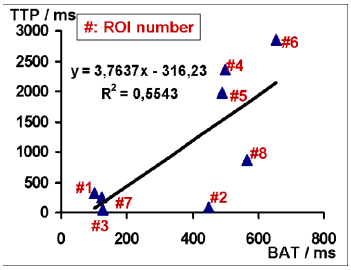

Fig.2: Mean delay values for ROIs from Fig.1 showing linear correlation

ROI	BAT / ms	BAT StdDev / ms	TTP / ms	TTP StdDev / ms
#1	590	103	1468	5812
#2	739	107	170	417
#3	358	23	0	0
#4	375	53	68	231
#5	633	25	410	483

Tab. 1: Mean values and standard deviations for ROIs from Fig. 3; small standard deviations from BAT map indicate good reliability of delay times in contrast to those obtained from DSC

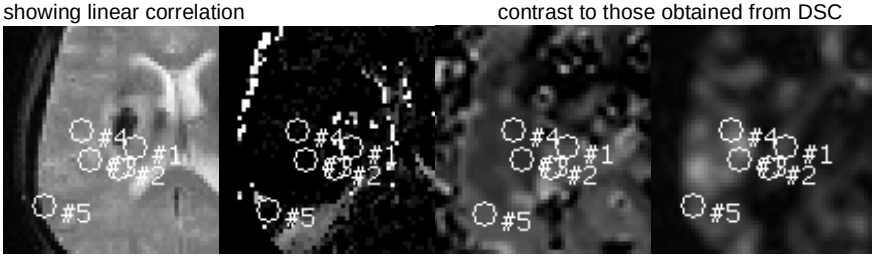

Fig.3: From left to right: T2 weighted image, TTP and BAT maps, CBF map derived from ASL for one selected patient; ROIs # 1 and 2 lie in penumbral area while # 3 and 4 in direct vicinity of the infarct core lie in an area of hypoperfusion.

Conclusion and outlook

The information from DSC and ASL is very much comparable in larger cortical areas that provide a good baseline for perfusion assessments due to the strong metabolism of neurons. For ASL, white matter and acute ischemic tissue are problematic due to low SNR at 1.5 T. In tissue that shows residual perfusion the relative contrast of healthy vs. ischemic tissue ASL showed similar and partially stronger contrast than DSC. Especially cortical inflow delay differences in the sub-second range can be resolved on BAT maps.

DSC is clinically widely applied and useful standard for stroke imaging. However, as this data demonstrates further optimization of ASL in regard to SNR and temporal-spatial dynamics for stroke assessment should be pursued as a strong contrast of pathological vs. healthy tissue is demonstrated in penumbral areas which are of particular interest.

References

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