

Multi-Delay Multi-Parametric Arterial Spin-Labeled Perfusion MRI in Acute Ischemic Stroke – Comparison with Dynamic Susceptibility Contrast Enhanced Perfusion Imaging

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Target Audience: Neuroradiologists, Neurologists and MRI scientists

Purpose: With the latest implementation using pseudo-continuous ASL (pCASL) and background suppressed 3D GRASE, it has been recently demonstrated that ASL can be reliably applied for acute stroke imaging, and provides largely consistent results with DSC mean transit time (MTT) and time to the maximum of tissue residual function (Tmax) maps for delineating hypoperfused brain regions (1). However, challenges and concerns remain regarding the accuracy of ASL CBF quantification in the presence of prolonged transit delays. In the present study, we present a multi-delay multi-parametric pCASL protocol. Its accuracy was evaluated by comparison with DSC perfusion MRI in 29 patients with acute and subacute ischemic stroke.

Methods: Consecutive middle cerebral artery (MCA) ischemic stroke cases were evaluated with both ASL and DSC as part of a complete MRI protocol, using Siemens MR scanners at 1.5 and 3T. ASL was acquired using a 4-delay pCASL protocol with background suppressed 3D GRASE (postlabeling delay or PLD=1.5/2/2.5/3s, FOV=22cm, matrix=64x64, 16x8mm slices, rate-2 GRAPPA, TE=22ms, 8 pairs of tag and control for each delay, total scan time 4min). After motion correction, mean perfusion image, $\Delta M(i)$, was generated for each PLD (i). A weighted delay, WD , was calculated by Eq [1] and converted into arterial transit time (ATT or δ) (2). CBF at each delay, $f(i)$, was calculated by Eq [2], and the final CBF was the mean of the estimated CBF at each PLD. Arterial CBV (aCBV) map was generated by the product of ATT and mean CBF of 4 PLDs.

$$WD = \frac{\sum_{i=1}^4 w_i \Delta M(i)}{\sum_{i=1}^4 \Delta M(i)} \quad [1] \quad f(i) = \frac{\lambda \Delta M(i) R_{1a}}{2 \alpha M_0 [\exp((\min(\delta - w(i), 0) - \delta) R_{1a}) - \exp(-(\tau + w(i)) R_{1a})]} \quad [2]$$

DSC scans were acquired using gradient-echo EPI (TR=2s, TE=45/30ms for 1.5/3T, matrix=128x128, 26x5mm slices, rate-2 GRAPPA). Post-processing of DSC yielded CBF, CBV, Tmax and MTT maps. In each case, all structural, diffusion and perfusion images were aligned using SPM8. Mean ASL and DSC perfusion parameters in left and right MCA territories were extracted and an asymmetry ratio was calculated as (contralateral-ipsilateral)/(contralateral+ipsilateral). Pearson correlation coefficients were calculated between asymmetry ratios of ASL and DSC for each of the perfusion parameters respectively.

Results: 29 patients (mean age 74.2±16.6 years; 16 men) with acute and subacute MCA ischemic stroke were imaged. The median imaging time to stroke onset was 4.7hr (range 1.6 to 44hr, if known). There were significant correlations between 4-delay pCASL and DSC asymmetry ratios of CBF (r=0.783, p<0.0001) and CBV measurements (r=0.480, p=0.0085). For ASL CBF acquired using the standard PLD of 2s, the correlation with DSC CBF was slightly reduced (r=0.742, p<0.0001). There were also significant correlations between pCASL ATT and DSC MTT (r=0.558, p=0.0017) as well as Tmax (r=0.636, p=0.0002) measurements. Fig. 1&2 show 2 representative stroke cases with increased CBF around the ischemic lesion using 4-delay pCASL compared to CBF using a single PLD of 2s. ATT is prolonged around the infarct in both cases, well matching DSC results.

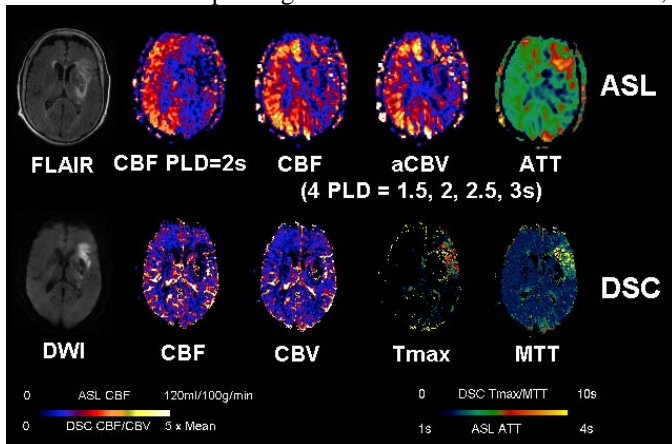


Fig. 1

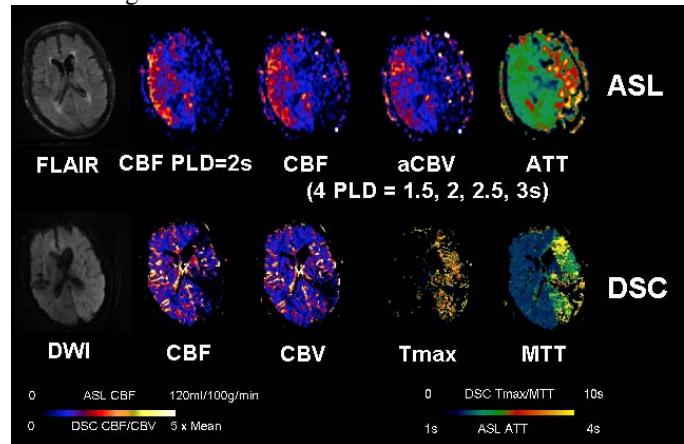


Fig. 2

Discussion and Conclusion: By taking into account prolonged ATT in perfusion quantification using a 4-delay pCASL GRASE protocol, the correlation between CBF measurements using pCASL and DSC was slightly increased from r=0.742 (PLD=2s) to 0.783, suggesting improved accuracy of CBF quantification in ischemic stroke. Similar to DSC, multiple perfusion parameters (CBF, CBV and ATT) can be estimated using multi-delay pCASL without penalty in scan time or SNR. Limited by T1 relaxation, ATT may not be accurately estimated in stroke cases with severely prolonged arterial transit delays (>3s). The capability for noninvasive multi-parametric perfusion imaging using ASL offers numerous opportunities for acute stroke imaging.

References: (1) Wang et al Stroke 2012; 43(4):1018-24; (2) Dai et al MRM 2012; 67(5):1252-65