Comparison of Pseudo-Continuous Arterial Spin-Labeled and Dynamic Susceptibility Contrast Enhanced Perfusion Imaging in Acute Ischemic Stroke

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Background: Imaging of the penumbra with MRI in acute ischemic stroke has mainly depended on the use of dynamic susceptibility contrast enhanced (DSC) techniques to identify regions of reversible injury. For instance, time to the maximum of the tissue residual function (Tmax) has been employed in clinical trials to define regions of hypoperfusion. Arterial spin-labeled (ASL) techniques provide cerebral blood flow (CBF) measures without the use of contrast. Recent technical advances rendered it feasible to apply ASL in the setting of acute stroke (1). In the present study, we conducted a systematic comparison of perfusion measures obtained using ASL and DSC perfusion MRI in acute ischemic stroke.

Methods: Consecutive acute ischemic stroke cases during a period of 6 months 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 pseudo-continuous ASL (pCASL) with background suppressed 3D GRASE (postlabeling delay=2s, FOV=22cm, matrix=64x64, 26x5mm slices, rate-2 GRAPPA, TR=4s, TE=22ms, 30 pair of tag and control acquired in 4min)(1). 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 perfusion images yielded ASL CBF maps and multiparametric DSC maps including CBF, CBV, Tmax and mean transit time (MTT)(2). In each case, all structural, diffusion and perfusion images were aligned using SPM8. Two experts independently reviewed ASL and DSC perfusion maps which were scored on a scale of 0-3 to rate image quality and lesion severity/conspicuity. Both hypo- and hyperperfusion were noted. Spearman correlation coefficients were calculated between average ratings of ASL and DSC perfusion maps, and a significance level of $p \leq 0.005$ was used to correct for multiple comparisons. Tmax>4s lesions were used to extract corresponding ASL CBF values and ASL CBF lesions < 15 mL/100g/min were used to measure Tmax values within co-registered ROIs of putative penumbra.

Results: Twenty-seven patients (mean age 71.0±15.7 years; 14 men) with acute ischemic stroke were imaged with pCASL and DSC. The median imaging time to stroke onset was 5.5hr (range 47min to 19hr). Serial imaging (up to 3 timepoints within the subacute period) with combined ASL and DSC was also obtained in a subset of 15/27 cases after endovascular therapies were implemented, resulting in a total of 45 scans. Both ASL and DSC image quality were excellent (2.2 and 2.5 on scale of 0-3, respectively). ASL CBF maps consistently demonstrated hypo- and/or hyperperfusion in regions corresponding to clinical symptoms and diffusion lesions. ASL was most consistent with DSC CBF (r=0.69, p=0.0001), and Tmax (r=0.55, p=0.003) maps in demonstrating hypoperfusion (see Fig. 1 case 1&3 baseline scan). ASL was also consistent with (r=0.60, p=0.001) yet more conspicuous than DSC CBF maps (1.1 vs. 0.6 on scale of 0-3, p=0.001, see Fig. 1 case 2&3 post treatment scan) in delineating hyperemic lesions. In contrast, DSC Tmax and MTT maps were virtually blind to hyperemic lesions. ROIs of potential penumbral zones (Tmax>4s) on DSC revealed mean ASL CBF values of 20.9±12.8 mL/100g/min. When mean DSC CBF values in control regions with Tmax ≤4s were calibrated using mean ASL CBF values in the same region (3), a strong correlation (r=0.67, p=0.001, Fig. 2) emerged between mean ASL and DSC CBF values in the penumbral zones defined by Tmax>4s (see Fig. 2). Delineation of penumbra on ASL (CBF<15 mL/100g/min) yielded mean Tmax values of 2.6±2.0s.

Conclusions: ASL CBF and DSC CBF, Tmax maps provided largely consistent results in delineating hypoperfusion lesions in acute ischemic stroke. ASL CBF, nevertheless, was more sensitive than DSC CBF in delineating hyperemic lesions which Tmax and MTT maps were unable to demonstrate. Hyperemic responses detected by ASL may be linked to luxury perfusion and may be associated with positive outcome in stroke (4). DSC CBF quantification may be improved by calibration using ASL CBF in control regions (e.g. Tmax≤4s) where arterial transit times are not severely prolonged (3). The utility of ASL to provide noninvasive and quantitative CBF information in acute stroke without the use of contrast agent offers numerous opportunities.

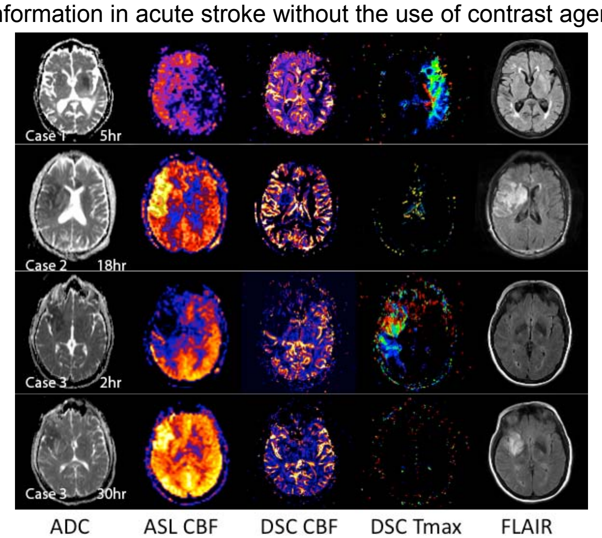

Fig. 1

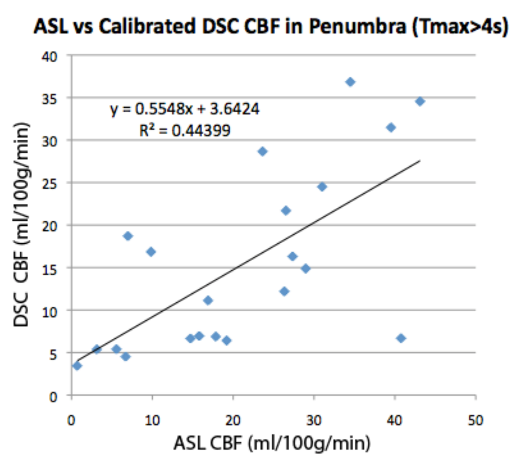

Fig. 2

References: (1) Fernandez-Seara et al. MRM 2008, 59:1467-71; (2) Kidwell et al. Ann Neurol 2000, 47:462-9; (3) Zaharchuk et al. MRM 2010, 63:1548-56; (4) Vlallon et al. Eur Neurol 2010, 64:286-296.