Comparison of multi-parametric ASL and CT perfusion in moyamoya diseases

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Target audience: clinicians and neuroimaging scientists.

Purpose: Moyamoya disease is characterized by the progressive stenosis or occlusion of terminal internal carotid arteries (ICAs). CT perfusion (CTP) is commonly applied for evaluating cerebral hemodynamics in moyamoya disease since it provides relatively accurate perfusion quantification including cerebral blood flow (CBF), cerebral blood volume (CBV) and mean transit time (MTT). Arterial spin labeling (ASL) offers a noninvasive method for quantifying CBF by using magnetically labeled arterial blood water as an endogenous tracer. However, delayed arterial transit times (ATT) through collateral pathways may cause underestimation of CBF using ASL. In this work, we present a novel multi-delay multi-parametric pseudo-continuous ASL (pCASL) protocol which was compared with CTP in 17 moyamoya patients.

Methods: Seventeen patients diagnosed with moyamoya disease were enrolled in this study. Both CTP and pCASL were examined in each patient. CTP was performed on a 16-section CT scanner (Somatom Volume Zoom; Siemens, Erlangen, Germany). Four contiguous sections with a slice thickness of 5 mm from the level of the basal ganglia/internal capsules to the upper portion of the lateral ventricles were obtained. MRI scans were performed on a 3T Siemens Trio Tim System using body coil transmitter and 12-channel head coil as receiver. The patients were scanned using pCASL with background suppressed (BS) 3D GRASE sequence (1). Imaging parameters were: TR/TE=4s/22.62ms, PLD=1.5/2/2.5/3s, label offset=90mm, voxel size= 3.44x3.44x5mm^3, 26 slices covering whole brain with a total scan time of 9.4min (4 PLDs). A M0 image was acquired. In addition, sagittal T1-weighted MPRAGE images were acquired for coregistration and to obtain the gray and white matter masks of each subject. The data were analyzed using SPM8, MATLAB and SPSS. After motion correction, mean perfusion image, ΔM(i), was generated for each PLD (i). A weighted delay, WD, was calculated by Eq [1] and converted into 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. MR and CT images were co-registered and the MR CBF maps were re-sliced to the space of CT perfusion maps.

$$WD = \left[\sum_{i=1}^{4} w_i \Delta M(i)\right] \Big/ \left[\sum_{i=1}^{4} \Delta M(i)\right] \quad [1]$$

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

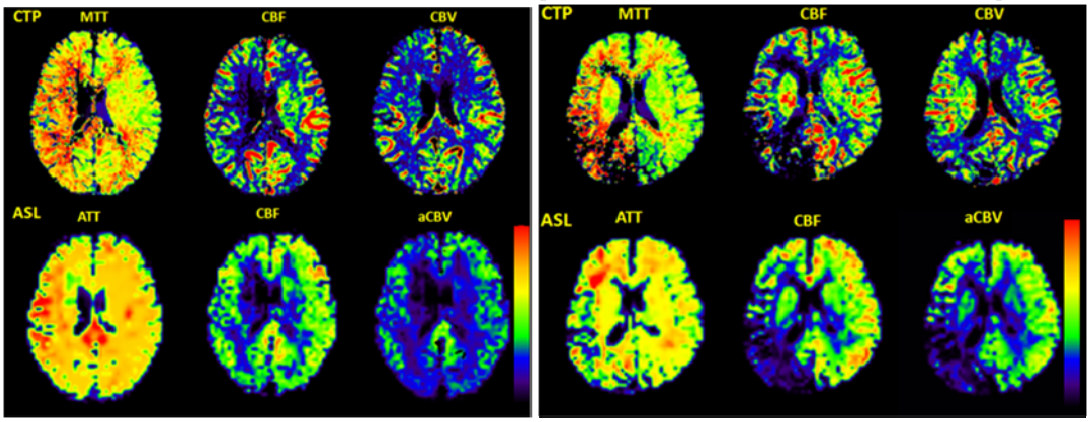

Fig.1 Comparison of CTP and pCASL in 2 moyamoya patients

Results: Two examples of the CTP (up) and pCASL maps (bottom) are shown as Fig1. In general, CTP CBF, CBV and MTT maps are highly consistent with ASL CBF, CBV and ATT maps. Table1 lists Pearson correlation coefficients between the two modalities across voxels in grey and white matter of each subject respectively. There were significant positive correlations (all $p<0.01$) between 3 pairs of parameters for each patient. Pearson correlation coefficients between normalized mean values of ASL and CTP in major vascular territories based on a published template (1) are listed in Table 2. Significant positive correlations were achieved for 3 pairs of parameters in the anterior cerebral artery (ACA), leptomenigeal MCA, perforator MCA and PCA ($r \geq 0.37, p<0.05$) territories except between ASL aCBV and CTP CBV in ACA and PCA.

Discussion: In summary, pCASL and CTP provided largely consistent results for the evaluation of hemodynamics in moyamoya patients, based on both intra- and inter-subject correlation analyses. By incorporating delayed ATT in CBF calculation, pCASL is able to provide quantitative multi-parametric perfusion imaging consistent with CTP in moyamoya disease.

Conclusion : The capability of pCASL to provide noninvasive multi-parametric perfusion information without the use of contrast agent offers the potential to include pCASL as part of standard neuroimaging protocol in the management of moyamoya disease.

Table 1. Pearson correlation coefficient (mean ± SD, n=17) between ASL and CTP

ASL ATT vs. CTP MTT			ASL CBF vs. CTP CBF			ASL aCBV vs CTP CBV		
GM	WM	global	GM	WM	global	GM	WM	global
0.475± 0.063	0.701± 0.042	0.708± 0.06	0.486± 0.073	0.493± 0.059	0.602± 0.051	0.412± 0.062	0.459± 0.058	0.471± 0.055

Table 2. Pearson correlation coefficient between normalized average values of ASL and CTP in major vascular territories of all 17 scans ($p<0.05$*, $p<0.005$**)

	ACA	Perforator MCA	Leptomeningeal MCA	PCA
ASL ATT vs.CTP MTT	0.664**	0.582**	0.466**	0.594**
ASL CBF vs. CTP CBF	0.37*	0.563**	0.798**	0.468**
ASL aCBV vs.CTPCBV	0.258	0.678**	0.215	0.644**

References: (1) Wang, Alger, Qiao, et al The Value of Arterial Spin-Labeled Perfusion Imaging in Acute Ischemic Stroke Comparison With Dynamic Susceptibility Contrast-Enhanced MRI. Stroke 2012; 43(4):1018-24;(2) Dai, Robson, et al. Reduced Resolution Transit Delay Prescan for Quantitative Continuous Arterial Spin Labeling Perfusion Imaging. MRM 2012; 67:1252-1265.

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