Comparison of Pseudocontinuous and Velocity Selective Arterial Spin Labeling with Gold Standard Xenon CT: a Study in Patients with Moyamoya Disease

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Introduction:
In standard arterial spin labeling (ASL), differences in arterial transit arrival time can be a major source of error in the quantification of cerebral blood flow (CBF). This problem becomes worse in some pathologies, such as stroke, where blood flow is slow and/or there is collateral flow. Recently, velocity-selective ASL (VSASL) (1) has been proposed and is expected to overcome this limitation. However, clinical data on VSASL is rare. In this study, we compared the performance of a 3D-FSE pseudocontinuous ASL (pcASL) (2) with different post-label delay (PLD) times and VSASL, using xenon CT CBF as gold standard.

Methods:
This study is a part of an ongoing project evaluating the performance of CBF measurement techniques in patients with cerebrovascular disease, and 8 patients with Moyamoya disease are included in this preliminary analysis. The MR sequences were performed at 3T (GE Healthcare MR750), and included 3D SPGR T1-weighted images, 3D-FSE pcASL with and without vessel suppression (the later referred to as pcASL-VS) (voxel size = 4x4x4mm^3, PLD =1s, 1.5s, 2s, 2.5s, and 3s) and VSASL (3.4x3.4x7.7mm^3, post label delay=1.6s). For VSASL, minimal-contrast and CSF maps were also acquired for quantitative calibration of the CBF measurement. Xenon CT (xeCT) perfusion imaging was performed using a GE 8-detector scanner, using previously described parameters (3). XeCT is considered a gold standard for CBF measurement, as inhaled xenon gas is a freely diffusible, stable tracer. MR and CT images were co-registered and the MR CBF maps were re-sliced to the space of xeCT CBF map. The T1-weighted image was segmented to create gray matter (GM) and white matter (WM) masks. The performance of pcASL, pcASL-VS and VSASL was compared by calculating the correlation coefficient with the xeCT CBF values. To account for noise and errors in registration, a voxel size of 1x1x1cm^3 was used. To further evaluate the accuracy of the different methods, mean CBF values were measured in the entire imaged brain region (BR) and in GM and WM using masks created above. ΔCBF was defined as the difference between ASL and xeCT CBF measurements. As 3 cases did not have adequate CSF maps to enable absolute scaling of VSASL CBF values, they were excluded from the analysis of mean values, leaving 5 patients in whom quantitative CBF was compared. However, since scaling does not affect correlation coefficient, they were included in the correlation analysis.

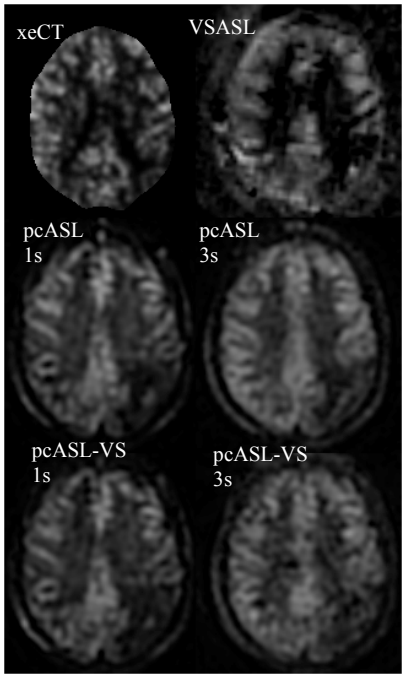

Fig. 1. CBF maps from different imaging techniques in a patient with bilateral Moyamoya disease and left parietal infarct.

Results:
High-quality pcASL, pcASL-VS, and xeCT CBF maps were obtained. VSASL CBF maps, however, have relatively lower SNR due to the use of a saturation rather than inversion labeling pulse (Fig. 1). Visually, PLD dependence of pcASL and pcASL-VS CBF measurement was obvious in slow-flow regions, though these were somewhat mitigated at longer PLD's, such as 3 s. Overestimation of CBF for pcASL studies with long PLD was seen in regions with delayed arrival, and may reflect differences in the true and assumed T1 decay of the label. Correlation analysis showed that among different PLD times, the strongest correlation with xeCT CBF measurement was found in CBF maps acquired with PLD=1.5s for both pcASL and pcASL-VS (Table 1). VSASL had moderate correlation with xeCT measurement, largely attributable to lower SNR in VSASL CBF measurement. In general, differences between VSASL and xeCT CBF values were among the smallest for all ASL sequences, and importantly the standard deviations of these differences were also small, suggesting that VSASL may provide a quantitatively more accurate measurement of CBF in these patients.

Table 1. shows correlation coefficient between xeCT and ASL CBF measurements, mean CBF values in the imaged brain region (BR), gray matter (GM) and white matter (WM). ΔCBF = (CBF from ASL) – (CBF in xeCT). CBF values are ml/100 g/min.

	xeCT	pcASL					pcASL-VS					VS-ASL
Post-label delay	n/a	1s	1.5s	2s	2.5s	3s	1s	1.5s	2s	2.5s	3s	1s
Correlation coefficient	1	0.58 (0.11)	0.582 (0.09)	0.55 (0.12)	0.50 (0.13)	0.45 (0.12)	0.57 (0.09)	0.57 (0.10)	0.50 (0.09)	0.44 (0.11)	0.41 (0.10)	0.45 (0.11)
CBF in BR	29.0 (4.4)	30.6 (2.3)	35.2 (1.7)	36.4 (1.6)	36.4 (3.1)	34.6 (4.9)	27.2 (2.9)	31.9 (2.5)	32.5 (0.9)	32.1 (2.1)	32.1 (1.9)	30.9 (3.9)
CBF in GM	35.9 (5.8)	37.2 (2.8)	43.6 (1.1)	45.4 (2.6)	45.4 (3.8)	43.0 (6.0)	33.0 (3.6)	39.3 (2.8)	40.1 (1.4)	39.3 (2.3)	38.8 (1.3)	37.2 (2.7)
CBF in WM	20.5 (3.2)	22.0 (2.6)	25.4 (2.9)	26.4 (1.6)	25.9 (2.0)	24.7 (2.8)	19.9 (2.8)	23.5 (3.6)	24.0 (2.3)	24.1 (2.4)	24.1 (2.9)	22.6 (6.5)
ΔCBF in BR		1.6 (4.1)	6.3 (4.2)	7.4 (4.1)	7.4 (3.3)	5.6 (4.9)	-1.8 (4.1)	3.0 (3.9)	3.6 (3.8)	3.2 (3.6)	3.1 (5.7)	2.0 (1.6)
ΔCBF in GM		1.3 (6.1)	7.7 (6.1)	9.5 (5.8)	9.5 (4.8)	7.1 (6.5)	-2.9 (6.2)	3.4 (5.1)	4.2 (5.6)	3.5 (5.0)	3.2 (7.4)	1.3 (4.9)
ΔCBF in WM		1.5 (3.3)	4.9 (3.1)	5.9 (3.3)	5.4 (1.6)	4.2 (2.6)	-0.6 (3.2)	3.0 (4.1)	3.5 (2.9)	3.6 (2.6)	3.6 (3.3)	2.1 (4.8)

Discussion: To our knowledge, these are the first reports of VSASL in clinical patients with severe prolongations in arterial arrival times. pcASL CBF maps with long PLD more closely approximated xenon CT CBF maps, but required long scan times (8 min) and had relatively poor SNR. The expected PLD dependence of pcASL and pcASL-VS CBF measurements was observed. VSASL provided more accurate absolute CBF measurement, though correlation with xeCT was lower, largely owing to lower SNR. Further development of VSASL techniques may enable accurate CBF measurements in patients with cerebrovascular disease.

References: 1. Wong MRM 2006. 2. Dai et al., MRM 2008. 3. Zaharchuk et al., MRM 2010.

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