Evaluation of random vessel-encoded ASL in both healthy subjects and stroke patients

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TARGET AUDIENCE: Scientists and clinicians interested in vascular territory mapping

INTRODUCTION: The ability to visualize cerebral perfusion territories is important for a number of clinical applications, such as the delineation of collateral circulations in stroke. Vessel-encoded ASL[1] offers the ability of imaging cerebral perfection territories from individual feeding arteries. However, prior knowledge of the positions of the feeding arteries is required in VE-ASL which is susceptible to field inhomogeneity at the labeling locations. Random VE-ASL (rVE-ASL)[2] was subsequently introduced to overcome the limitations of VE-ASL, and can detect the feeding arteries without prior knowledge and map the corresponding vascular territories. In the current study, we evaluated the feasibility of rVE-ASL in a cohort of healthy subjects by comparison with the standard VE-ASL, and in a cohort of stroke patients by comparing to digital subtraction angiography (DSA).

METHODS: All the experiments were performed on Siemens 3T TIM Trio scanner using a 12-channel head coil. 7 healthy volunteers (2 males, 32.4±8.5yrs) underwent random VE-ASL scans with background suppressed (BS) single-shot 3D GRASE acquisition with the following parameters: FOV= 220×220 mm^2, matrix size=64×64, TE/TR=22/3500ms, 16 slices with slice thickness of 6mm, 60 pairs of encoding steps with random orientation, phase and wavelength were acquired with two additional pairs of global label/control for a total scan time of 7min 14s. For comparison, VE-ASL with BS 3D GRASE was also performed on each subject with closely matched imaging parameters. 48 pairs of VE-ASL data were acquired with the scan time of 5min 36s. During the data processing of rVE-ASL, the locations of feeding arteries were identified by the correlation coefficient (CC) between the acquired perfusion signal and a database of predicted signal distributions, and the corresponding perfusion territorial maps were subsequently obtained based on the highest CC in each voxel[2]. We divided the perfusion territories into 3 regions: right and left internal carotid arteries (RICA and LICA), and basilar artery (BA). The territorial maps between rVE- and VE-ASL were quantitatively compared using Dice similarity coefficient (DC)[3], defined as the ratio between the number of voxels in the intersection of two regions, and the mean volume of both regions.

Five ischemic stroke patients were recruited in this study. Random VE-ASL was performed on each patient. Digital subtraction angiography (DSA) was also acquired from 4 of the patients. Collaterals were evaluated in the LICA, RICA, and BA territories on rVE-ASL and DSA independently according to the following criterion[4]: 0: poor, no collateral circulation; 1: intermediate, partial collateral flow to the ischemic region; 2: good, full collateral flow to the site of occlusion; 3: normal antegrade flow.

RESULTS: The cerebral vascular territory maps were obtained from rVE-ASL and VE-ASL from each healthy subject. The locations of feeding arteries were mostly detected using rVE-ASL. Figure 1 shows an example of vascular territory maps from a healthy subject. One can appreciate the similar spatial patterns of perfusion territories between rVE- and VE-ASL. The quantitative measurements of the spatial overlap between these two ASL acquisitions are shown in Figure 2. The territories of RICA and LICA with rVE-ASL were well matched with those of VE-ASL (DC_{RICA}=0.89±0.05, DC_{LICA}=0.87±0.03). There was relative poorer overlap of the territory of BA (DC_{BA}=0.23±0.17). All the territory maps using rVE-ASL were acquired from each patient. The scoring of collaterals by rVE-ASL was in good agreement with DSA (Table 1). Figure 3 displays the perfusion territory map (a,b) and DSA (c-e) from one patient who had total occlusion of LICA and collaterals were formed through RICA (red arrow), BA (green arrow) and LECA (left external carotid artery, blue arrow) from retrograde blood flow via ophthalmic artery.

Table 1. Evaluation of collaterals on rVE-ASL and DSA

Patient No.	rVE-ASL			DSA		
	LICA	RICA	BA	LICA	RICA	BA
1	2	0	3	2	0	3
2	2	3	3	2	3	3
3	1	3	3	2	3	3
4	1	3	3	1	3	3
5	3	3	3	--	--	--

0: poor, no collateral circulation;
1: intermediate, partial collateral flow to the ischemic region;
2: good, full collateral flow to the site of occlusion;
3: normal antegrade flow.

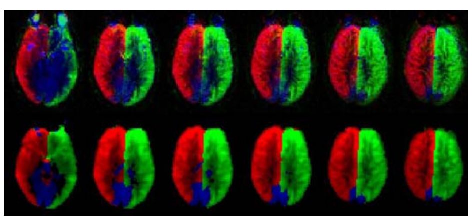

Fig. 1 the perfusion territory maps using rVE-ASL (top) and VE-ASL (bottom) from a healthy subject

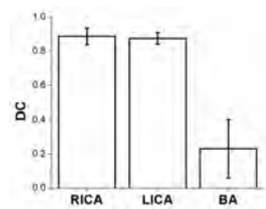

Fig. 2 DC for the perfusion territories of right and left ICA and BA between rVE-ASL and VE-ASL across subjects.

DISCUSSION: In this study, we demonstrated the feasibility of rVE-ASL on both healthy subjects and stroke patients. Consistent perfusion territory maps were obtained between rVE- and VE-ASL, especially in left and right ICA. The lower DC in BA may be caused by the effect of the magnetic field inhomogeneity on VE-ASL or lower labeling efficiency in BA. Collaterals from either intracranial arteries (such as ICA or VA) or extracranial artery (such as ECA) can be clearly detected and graded in the stroke patients using rVE-ASL, which shows the potential utility of rVE-ASL on the characterization of collateral circulation in ischemic stroke.

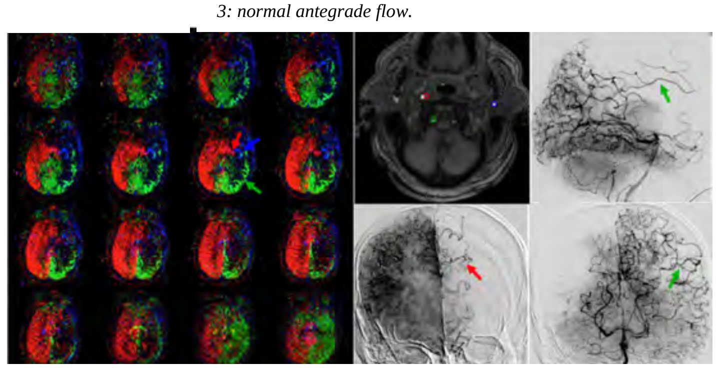

Fig. 3 Perfusion territory images (a) and the detected locations of feeding arteries (b) using rVE-ASL, and the DSA images (c-e) from one stroke patient. LICA is occluded. The collaterals can be seen clearly from RICA(red arrow), BA(green arrow) and LECA (blue arrow) on both rVE-ASL and DSA.

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