Reproducibility of flow territories defined by plannings-free vessel encoded pseudo-continuous arterial spin labeling

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Introduction

Selective arterial spin labeling MRI (or regional perfusion imaging, RPI) has the unique capacity to show the perfusion territories of brain feeding arteries non-invasively. Perfusion territory information might add valuable information in patients with acute or chronic ischemia, large vessel stenosis or occlusion and arteriovenous malformations. In the past years different ASL methods have shown promising results in several of these patient populations [1]. However no study has investigated the reproducibility of these selective ASL methods. Whereas the first implementations required time-consuming planning of a labeling plane over individual arteries, the recent introduction of vessel encoded pseudo-continuous arterial spin labeling has enabled a complete plannings-free acquisition of all major flow-territories within 5 minutes [2].The clinical applicability of this method is highly dependent on reliability and accuracy with which different flow territories can be identified. Therefore the aim of the present study was to determine whether RPI based flow territories are imaged sufficiently reliable and accurate to be used in a clinical setting.

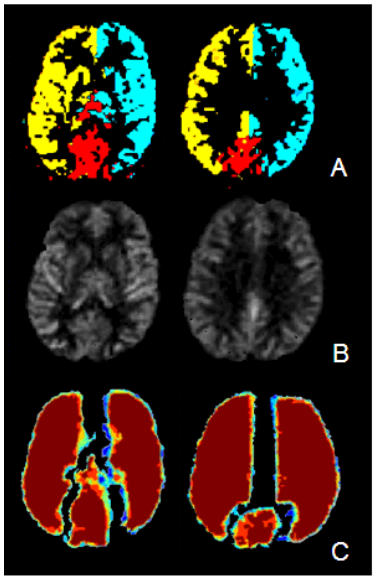

Figure 1: (A) RICA, LICA and BA flow territories, (B) non-selective perfusion weighted images obtained from RPI scan, (C) overlap of flow territories obtained from different sessions, with dark blue 1, light blue 2, green 3, yellow 4, red 5, dark red 6 territories overlapping.

Methods

Reproducibility of RPI was assessed at three imaging centers in the Netherlands, all equipped with a Philips 3T Intera MR scanner with the same implementation of vessel encoded pseudo-CASL. Local ethics committees approved this study and the six healthy participants (five male; age 25-50) gave written informed consent. Volunteers were scanned twice at each site with 1 to 3 weeks between sessions. The imaging protocol consisted of a RPI scan and a high resolution 3D T1-weighted anatomical scan for registration and segmentation purposes. All scans were acquired with a SENSE-8-channel head coil and body coil transmission. RPI imaging parameters were: TR/TE 4000/14 ms; FOV 240×240; matrix size 80×79; slices 17; slice thickness 7 mm; no slice gap; single shot EPI; post labeling delay 1525 ms; background suppression; number of dynamics 80. The labelling efficiency was spatially manipulated within the labelling plane in sets of 5 dynamics: no labelling (control), non-selective labelling (globally perfusion weighted), labelling varied in right-left direction (distance of 50 mm between fully labelled and control situation), labelling varied in anterior-posterior direction (distance of 18 mm) and labelling varied in anterior-posterior direction (distance of 18 mm, but shifted 9 mm in posterior direction compared to the previous dynamic). Following the procedures outlined in [2], the relative labelling efficiencies of the RL, AP1, and AP2 manipulated scans were calculated and three flow territories were identified by means of k-means clustering. To improve the outcome of the clustering algorithm also the x, y, and z coordinates of each voxel (normalised by half the FOV in that direction) were included as features in the clustering [3]. The RPI perfusion image and RPI defined flow territories of basilar (BA) and left and right internal carotid arteries (RICA and LICA), were transformed into anatomical space by registration on corresponding anatomical scans. Subsequently, the three main flow territories were manually segmented on the basis of the outcome of the clustering algorithm. To achieve a measure of the uncertainty in the identification of the boundaries of the flow territories, the edge pixels of the flow territory were determined; edge pixels located at the brain surface were discarded, since the interesting boundaries are the ones that separate two flow territories. For each pair of repeated RPI scans (e.g. LICA session 1 versus LICA session 2, RICA session 1 versus RICA session 2, and BA session 1 versus BA session 2) the mean and the maximum distance between the edge pixels was calculated. Both measures were averaged for all combinations of the 6 repeated scans per volunteer and averaged over all subjects. Furthermore, the difference between inter- and intracenter reproducibility was tested for significance using paired t-tests, with P values < 0.05 regarded significant.

Results

Comparison of flow territory data indicated that for all but one individual all repeated RPI scans of all sessions and imaging centers yielded approximately the same flow territory maps. For one person 2 out of 6 scans showed an erroneously enlarged posterior flow territory, taking over about half of the flow territory of the LICA. When decreasing the influence of the spatial features in the clustering algorithm, the posterior flow territories became comparable to the other 4 scans. This volunteer was excluded from further analysis. *Figure 1* shows two slices of RPI data from one individual with the flow territories of a single scan (*Figure 1A*), the non-selective perfusion weighted image that is also obtained from the RPI scan (*Figure 1B*) and the overlap of flow territories gathered from different sessions at different sites (*Figure 1C*). Measurement of the mean distance between the edge pixels gathered from intracenter data indicated 2.7 ± 0.8 mm, 3.1 ± 1.1 mm and 2.5 ± 0.7 mm for LICA, RICA and BA flow territories respectively (see *Table 1*). Measurement of the mean distance between the edge pixels gathered from intercenter data indicated 3.2 ± 0.8 mm, 3.4 ± 1.2 mm and 2.6 ± 0.6 mm for LICA, RICA and BA flow territories respectively. These mean intra- and intercenter distances differed significantly (P=0.04). The maximum intra- and intercenter differences did not differ significantly. The maximum distances between edge pixels are shown in *Table 1*. Mean and maximum distances between edge pixels gathered from intracenter data were not significantly different between imaging sites.

Intracenter	LICA	RICA	BA
Mean distance			
Site 1	2.4 ± 1.3	2.9 ± 1.7	2.4 ± 0.9
Site 2	3.1 ± 1.0	3.5 ± 1.8	2.8 ± 1.2
Site 3	2.6 ± 0.9	2.9 ± 1.4	2.2 ± 0.7
Mean sites 1,2,3*	2,7 ± 0.8	3.1 ± 1.1	2.5 ± 0.7
Max distance			
Site 1	7.8 ± 4.1	10.3 ± 4.5	8.2 ± 3.1
Site 2	10.8 ± 2.8	12.9 ± 6.7	9.6 ± 3.8
Site 3	8.9 ± 2.6	10.7 ± 5.0	8.4 ± 2.6
Intercenter	LICA	RICA	BA
Mean distance*	3.2 ± 0.8	3.4 ± 1.2	2.6 ± 0.6
Max distance	11.8 ± 4.1	10.7 ± 3.0	8.8 ± 2.4

*Table 1: Mean and max distances (in mm) between flow territory edge pixels obtained from different RPI scans. * The mean intracenter distance differed significantly from the mean intercenter distance.*

Conclusions

The results of this work show that RPI based flow territories are imaged sufficiently reliable and accurate to be used in a clinical setting. For all but one individual all repeated RPI scans yielded approximately the same flow territory maps. The mean distance between edge pixels obtained from different RPI sessions are on the order of 2.5 to 3.5 mm. Intracenter distances were significantly smaller than intercenter distances. Intracenter distances were of the same order of magnitude for all participating sites. Plannings-free RPI could thus be a valuable tool for identification of different flow territories and quantification of regional perfusion.

References

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