Whole brain cerebral flow territory mapping using vessel selective dynamic arterial spin labeling within 30 seconds

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Target audience: Researchers interested in new acquisition approaches in arterial spin labeling

Purpose: Territory information is important in patients with large vessel disease, e.g. in acute stroke patients, to identify the source artery of emboli. A standard whole brain territory mapping sequence using vessel selective arterial spin labeling (VS-ASL) takes about 5 minutes[1], which is frequently considered too long for addition to clinical protocols. This long scan duration is caused by the need for an additional non-selective perfusion map to calculate relative labeling efficiency maps, and because each encoding pattern is implemented as a standard ASL scan with long labeling duration and post-labeling delay, as illustrated in figure 1A. For more widespread clinical use and especially in the acute setting, imaging must be performed much faster. In a previous study, vessel selective dynamic arterial spin labeling (VS-DASL) was proposed and proved to be capable of providing cerebral flow territory information from the main cerebral arteries within a very short scan duration of 10s-30s[2]. However, the main disadvantage of this technique was that it was restricted to a single slice, since readout pulses of the lower slices in multi-slice imaging would disrupt the encoding pattern for the more distal slices. In this study, VS-DASL is combined with a single shot 3D Turbo-Field Echo-Planar Imaging (3D TFEPI) readout to achieve faster whole brain flow territory mapping.

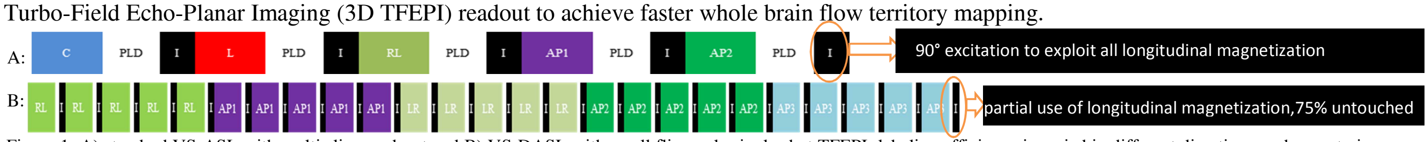

Figure 1: A) standard VS-ASL with multi slice read-out and B) VS-DASL with small flip angle single shot TFEPI: labeling efficiency is varied in different directions such as anterior-posterior (AP) and right–left(RL); imaging is represented by (I)

Methods: VS-DASL is based on the creation of a continuous stream of label/control blocks with different encoding patterns for each feeding artery, whose inflow into the brain tissue is monitored continuously. Based on simulations, a single encoding pattern was chosen to be repeated 5 times (400-1000ms labeling interleaved with imaging modules of 235ms each, figure 1B). This approach leads to unique signal fluctuations for each flow territory enabling reconstruction of flow territories by means of clustering techniques[3] followed by a linear regression step. In addition to the different readout technique compared to the previous single slice VS-DASL study, the sequence was further optimized by using two opposite right-left encoding patterns (RL-LR) instead of equal patterns (RL-RL). This guarantees signal fluctuations in both left and right flow territories, since both experience the control as well as label conditions and thereby improve the linear regression analysis.

Five healthy volunteers were scanned under a local IRB approved protocol. 3D VS-DASL was implemented on a 3T MRI scanner (Philips Healthcare) using a 32ch head coil with labeling durations of 400ms, 600ms, 800ms and 1000ms; for all scans the post labeling delay was 32ms, flip angle 11°, TFE factor 15, single shot 3D TFEPI readout with 25 slices, spatial resolution 3.75×3.75×3.75mm^3, total scan time 18/22/30/38s for 400ms, 600ms, 800ms and 1000ms labeling duration, respectively. A standard deviation map was created using the first two read-outs, which enabled the creation of a gray matter mask from the differential T1-weighting. The other 23 read-outs were sent to a k-means clustering analysis of all voxels within the gray matter mask, followed by a voxel-wise linear regression analysis employed to obtain the final territory maps. Traditional VS-ASL scans were acquired to validate 3D VS-DASL, using multi-slice single-shot EPI, 1650ms labeling duration, 1550ms post-labeling delay and flip-angle of 90°. Validation was performed by calculating the Dice similarity coefficient, which represents the fractional overlap between two binary images [4].

Results: Figure 2 shows the Dice similarity coefficient between territories acquired by 3D VS-DASL and VS-ASL when using different labeling durations. The Dice similarity coefficient increased with longer labeling duration, although a plateau was reached above 800ms. Figure 3 shows the flow territories obtained by 3D VS-DASL (blocks of 800ms labeling duration) for slice-number 11-15 with the corresponding slices of the traditional VS-ASL sequence. The results are in good agreement with standard VS-ASL and demonstrate that the output of the linear regression provides CBF-weighting within the flow territory maps.

Discussion: Single shot 3D TFEPI is a very efficient readout technique, which has the advantages of fast read-out, a short echo time, high SNR and only minor disruption of the encoding pattern (only 24% of magnetization was saturated due to a single readout module consisting of fifteen 11° RF-pulses). However, due to the blurring artifacts of the 3D readout, spatial resolution is decreased compared to the traditional VS-ASL and the single slice VS-DASL. The quality of the obtained territory map increased with longer labeling duration, partly due to the slightly longer scan-times (however we tested by doubling the scan-time when using 400ms labeling duration, it indeed increased the DC but was still worse than scans with longer labeling duration), but mainly due to the improved balance in time spent between labeling and read-out (235ms). Using a labeling duration of 800ms provided a high quality flow territory map in 30s. This technique provided consistent image quality in all subjects. Since previously it had been shown that linear regression analysis is able to identify mixed perfusion[4], it might be expected that the same holds true for 3D VS-DASL, but this needs to be verified.

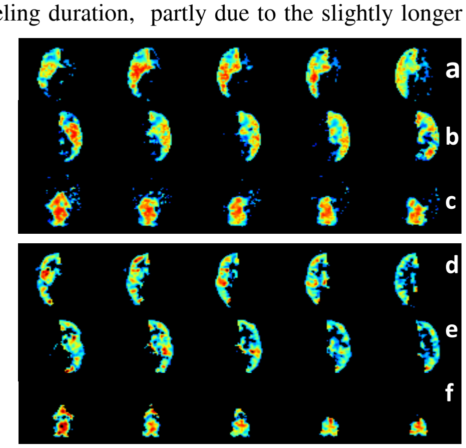

Figure 3: 3D VS-DASL flow territories of the right internal carotid (RICA, a), of the left internal carotid (LICA, b) and of the vertebral arteries (VAs, c). Traditional VS-ASL flow territories of the RICA (d), of the LICA (e) and of the VAs (f) are shown in the bottom panel.

Conclusion: Single shot 3D TFEPI VS-DASL has the potential to map the main flow territories with whole brain coverage in a very short scan duration of 30s, enabling its use in patients with acute stoke.

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References: [1] Gevers *et al.*, AJNR Am J Neuroradiol. 2012 Feb;33(2):E21-5

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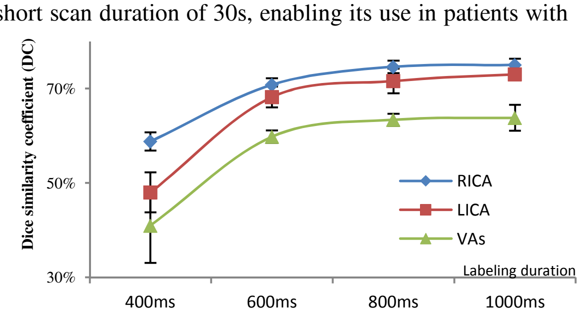

Figure 2. the Dice similarity coefficient as a function of the labeling duration.