Fast cerebral flow territory mapping using vessel selective dynamic arterial spin labeling

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

Purpose: Vessel selective arterial spin labeling (VS-ASL) provides important clinical information by mapping the flow territories of the main cerebral arteries1[1]. In current clinical protocols, this standard VS-ASL takes about 5 minutes2[2]. Territory information might especially be beneficial in acute stroke patients, e.g. to identify the source artery of emboli. However, for the acute setting, imaging should be performed much faster to be clinically acceptable. Traditional VS-ASL sequences are time-consuming because an additional non-selective perfusion map is required to calculate relative labeling efficiency maps and it employs delay times on the order of 1.5s to allow the label to reach the brain tissue3[3]. To achieve faster flow territory mapping, we propose the use of dynamic ASL (DASL)4[4] combined with VS-ASL (VS-DASL).

Methods: DASL is based on alternate continuous labeling and non-labeled condition interleaved with imaging. A single dynamic in DASL consists of 5-20 repetitions of interleaved labeling (200-400ms) and imaging (35ms) modules and an equal number of control and imaging modules4[4]. The main concept behind VS-DASL is to create a continuous stream of label/control blocks, whose inflow into the brain tissue is monitored continuously, with different encoding patterns for each feeding artery. This approach leads to unique signal fluctuations for each flow territory enabling reconstruction of flow territories by means of clustering techniques1[1] or independent/principal component analysis. The main differences with traditional VS-ASL are that imaging is performed at a much higher sampling rate (every 200-400ms) and that a continuous inflow of spatially encoded label is achieved. VS-DASL was implemented on a 3T MRI scanner (Philips Healthcare) using a 32ch head coil with a label duration of 1650ms, post-labeling delay (PLD) 1525ms, flip angle 90°, readout time and thus the delay between two DASL-blocks. Furthermore, multi-slice imaging would increase the readout time and thus the delay between two DASL-blocks. Multi-slice imaging will disrupt the encoding pattern for more distal slices. Single-shot 3D sequences might provide a good basis for volumetric coverage.

Discussion: The percentage of correctly classified voxels shows that VS-DASL can provide similar flow territory information as standard VS-ASL in a scan time of only 30-60s. With longer scan times, the results are more accurate, but our results show that the degree of accurately-classified voxels has reached 78% when only the first dynamic was used. Shorter DASL-block size of 200ms led to worse results, probably because the inflowing magnetization accumulates in brain tissue while gradually decaying according to T1: the accumulation of label effectively dampens the encoded signal variations when the effective block length (five times 200ms) becomes short compared to the T1 of the label. Currently VS-DASL is restricted to a single slice, since multi-slice imaging would increase the readout time and thus the delay between two DASL-blocks. Furthermore, multi-slice imaging will disrupt the encoding pattern for more distal slices. Single-shot 3D sequences might provide a good basis for volume coverage.

Conclusion: VS-DASL has the potential to map the flow territories in a short scan time (~30-60s), enabling use in, for example patients with acute stroke. This sequence enables fast flow territory mapping due to a high sampling rate combined with a continuous inflow of spatially encoded label. The use of a frequency map of the raw dynamic signal enables the creation of a gray matter mask.
