A Framework for Motion Correction of Background Suppressed Arterial Spin Labeling Perfusion Images Acquired with Simultaneous Multi-Slice EPI

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Introduction:

Simultaneous multi-slice (SMS) EPI excites multiple slices at the same time, thereby reducing the number of excitations per TR, which is advantageous for fMRI and DTI. For ASL in which background suppression (BS) is employed to reduce physiological noise from background tissue, however, SMS excitation results in slices with the most and least effective BS are located next to each other, thereby producing discrete dark lines (Figure-1). When motion occurs in the slice direction, it develops two major problems: (i) the discrete dark lines hamper accurate motion estimation, and (ii) different level of BS between control and label conditions causes severe subtraction errors. The aim of this work is to present a new MoCo framework for SMS-BS-ASL to solve these problems.

Figure-1: Discrete dark lines caused by BS-SMS acquisition.

Methods:

The proposed framework consists of three steps: (1) Homogenize the background signal difference over slices, by applying a BS factor per slice as obtained from the ratio of the mean tissue value of the M0 and the SMS-BS-ASL scan. (2) MoCo using the conventional software such as FSL and SPM. (3) General linear model (GLM): $\boldsymbol{y}=[\boldsymbol{x}_{perf}\boldsymbol{x}_{error}][\beta_{perf}\beta_{error}]+c$, where $\boldsymbol{y}$ is the motion corrected ASL time-series at a certain voxel, $\boldsymbol{x}_{perf}$ is the labelling paradigm $[0.5, -0.5, \ldots, 0.5, -0.5]^T$ multiplied by the BS factor to correct for the scaling of the perfusion signal during the homogenization step, $\boldsymbol{x}_{error}$ represents estimated artefactual signal changes induced by MoCo, obtained by subtracting the ASL images before and after MoCo, β_{perf} and β_{error} are fitting coefficients for $\boldsymbol{x}_{perf}$ and $\boldsymbol{x}_{error}$, respectively, c is the residual signal. **[Simulation]:** SMS-BS-pCASL images were simulated after applying 6 different motions (translation in the x/y/z-direction and rotation around the x/y/z-axis). These data underwent the processing described above and the CBF map was generated (NewMoCo). For comparison, CBF maps were also generated without MoCo (NoMoCo) and with MoCo without the homogenization (StdMoCo). **[In-vivo study]:** Functional-ASL scans were performed with visual and motor stimuli. Healthy volunteers were instructed to move their head during scans. These data were processed by NewMoCo, NoMoCo and StdMoCo.

Results:

The simulation resulted in severe subtraction errors with StdMoCo when through-plane motion was corrected. By applying NewMoCo, subtraction such errors decreased significantly. As Figure-2 shows, the best depiction of the activated area was obtained by NewMoCo.

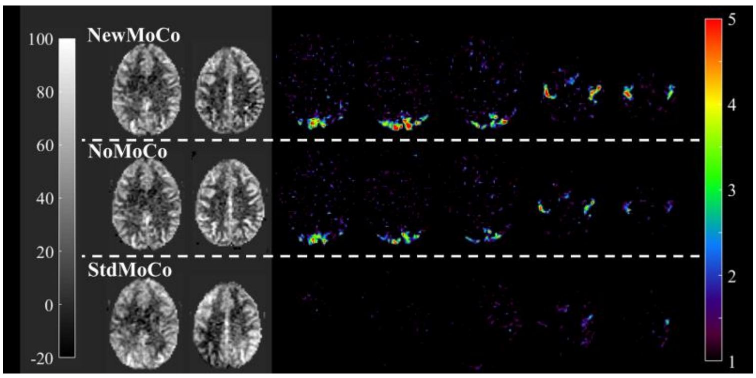

Figure-2: Baseline CBF maps and t-value maps showing the activated regions by stimuli obtained by using NewMoCo, NoMoCo and StdMoCo, in in-vivo study.

Conclusion:

In SMS-BS-ASL, severe subtraction errors occur when through-plane motion is corrected by StdMoCo. With the proposed framework, these subtraction errors could be minimized, resulting in improved accuracy of CBF-estimation.