Improving Motion Robustness of Pseudo-Continuous Arterial Spin Labeling by using real-time Motion Correction

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INTRODUCTION

Arterial Spin Labeling (ASL) is a completely non-invasive method that utilizes magnetically labeled blood as endogenous tracer. Perfusion-weighted images are generated by subtraction of several image pairs with (label) and without labeling (control) of inflowing blood so that signal from static tissue is canceled out. However, this makes the method sensitive to even little motion and can result in subtraction artifacts and blurred cerebral blood flow (CBF) maps. Background suppression already improves ASL image quality, but cannot compensate for macroscopic subject motion [1]. More recently, a promising method employing prospective motion correction for pseudo-continuous ASL (pCASL) was introduced for improved image quality [2]. In this study, motion correction (MoCo) tracker scans are performed within the labeling delay of a conventional pCASL sequence, thus, without extending initial scan time and without affecting CBF measurements.

MATERIALS and METHODS

2D MoCo tracker images consisting of three orthogonal slices are acquired within the delay time after blood labeling and before ASL image acquisition to continuously measure the position of the head (fig. 1, top) [3]. Subsequently, the tracker images are registered to a previously acquired set of reference images. In case of head motion, the geometry parameters of the MoCo tracker are adapted (translation, rotation) according to the registration outcome and another MoCo scan is performed to check the new set of geometry parameter. This process is repeated until the registration of reference and MoCo tracker images present negligible differences. The orientation of the imaging volume finally is adapted according to the new head position. Usually, only a couple of MoCo tracker acquisitions are required to adapt the new image coordinates after head movement. However, since the labeled blood already disappeared after more than one MoCo tracker scan, the acquisition module is skipped and a labeling module is performed instead (fig. 1, bottom). If motion is detected between corresponding label and control images, a complete pair of label and control images is reacquired in order to minimize subtraction artifacts due to small differences between adapted label and control images. The approach was evaluated in 5 healthy volunteers on a Philips 1.5T Achieva scanner using an 8-channel multi-array coil for signal reception. Four scans were performed per volunteer with and without controlled head motion during scanning as well as with and without MoCo tracker application. ASL scan parameters were: FOV 240×240 mm^2, voxel size 2.7×2.7×6mm^3, 15 slices, gradient echo planar read-out (EPI). Labeling duration 2.0 s, postlabeling delay 1.2 s, and 20 pairs of label and control images. Scan time was approximately 2:40 min. MoCo tracker scan parameters were: FOV 240×240 mm^2, voxel size 3.75×3.75×20 mm^3, three orthogonal slices, fast gradient echo acquisition, TR/TE 3.5/1.6 ms. Scan time was 0.492 s. CBF maps were generated according to[4] and correlation coefficients were calculated between the first volume and the following acquisitions within one pCASL scan.

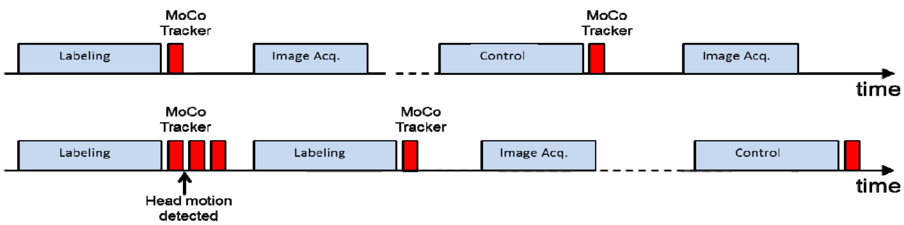

***Figure 1**: Sequence diagram of 2D motion correction (MoCo) tracker to continuously measure the position of the head during the labeling delay in a pCASL sequence (top). In case of head motion, MoCo tracker acquisition and subsequent registration are repeated until the registration of reference and MoCo tracker images present negligible differences (bottom).*

RESULTS

Subject motion was successfully detected in all volunteers. In figure 2, representative CBF maps of two volunteers are shown that demonstrate similar image quality for measurements with and without MoCo tracker application. Overall image quality in scans with head motion is qualitatively improved with respect to blurring and subtraction artifacts when compared with conventional pCASL without MoCo. This is also reflected in quantitative analysis of grey matter CBF and correlation coefficients (table 1).

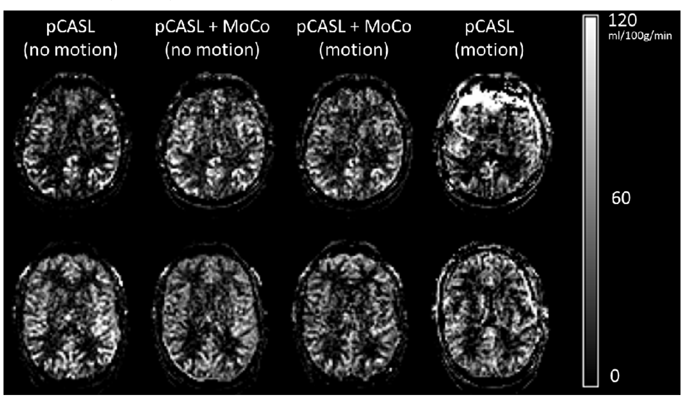

***Figure 2:** Representative CBF maps of two different volunteers (top and bottom row) demonstrate reduced subtraction artifacts and image blurring by the application of MoCo trackers without affecting CBF measurements.*

***Table 1:** Quantitative CBF measurements and corresponding correlation coefficients averaged over 5 volunteers for pCASL scans with and without controlled subject motion and with and without the application of MoCo tracker scans.*

	pCASL (no motion)	pCASL+MoCo (no motion)	pCASL + MoCo (motion)	pCASL (motion)
CBF (ml/100g/min)	46.1 ± 17.4	45.2 ± 10.7	45.4 ± 9.0	45.9 ± 11.8
Corr. Coeff.	0.99 ± 0.01	0.99 ± 0.01	0.98 ± 0.1	0.91 ± 0.05

DISCUSSION

By the application of MoCo tracker scans in conjunction with conventional pCASL, perfusion measurements can become more robust against subject motion during scanning. The MoCo tracker is performed within the delay time between blood labeling and image acquisition, thus, does not initially increase the total scan time of the sequence. CBF measurements were not affected by the acquisition of MoCo tracker images (table 1), but the dead time between MoCo tracker and ASL image acquisition (~700ms) will allow for subject motion without detection. MoCo tracker acquisition immediately before ASL image acquisition would increase the probability for detecting subject motion [2], but may also alter the image quality of ASL images. Another limiting factor is that EPI distortions linked to magnetic susceptibility changes, eddy currents etc. can significantly degrade the image quality even when the MoCo tracker correctly detects motion and image coordinates are adapted accordingly. In this study, only controlled head motion was performed of the head in order to reduce effects by EPI distortions. In addition, the size of the receive coil only allowed limited translation and rotation of the head. This is reflected in reasonably high correlation coefficients even in case of head motion (table 1). However, at higher field strength, EPI distortion effects will increase and may require further consideration in addition to the proposed MoCo approach. Further evaluation of the presented MoCo compensation technique is required with a larger number of volunteers and with random motion in order to verify the results and estimate the potential of this approach for clinically performed pCASL measurements in patients.

REFERENCES: [1] Garcia DM et al, Magn Reson Med 2005;54:366-372; [2] Zun Z et al, Magn Reson Med 2014;72:1049-56;
[3] Nielsen T et al, Proc. Ann. Meeting ISMRM : #2472; [4] Alsop DC et al, Magn Reson Med 2014 (epublished)