Prospective motion correction for artefact reduction in pseudo-continuous arterial spin labelling with a 3D GRASE readout.

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Introduction: Arterial spin labelling (ASL) is a non-invasive method for the measurement of blood perfusion, and has found particular importance in neurological applications [1]. ASL is however, an inherently low SNR sequence, with blood perfusion accounting for 1-2% signal intensity change. ASL is also highly susceptible to misalignment between label and control images, which produce errors in the perfusion weighted subtraction image. Therefore, ASL sequences are typically a compromise between speed of acquisition and SNR: Longer durations (multiple averages and segments) increase the chance of motion-induced errors, leading to image data of non-diagnostic quality. In this study, we adapt a segmented pseudocontinuous ASL (pCASL) labelling scheme with a GRASE readout [2,3] with prospective motion correction (PMC), allowing for scans of longer duration, such as segmented approaches or increase number of signal averages without motion-induced artefacts.

Methods: Five healthy subjects underwent an MR examination, in which images were acquired with a pCASL sequence with a PMC enabled 3D GRASE readout (labelling was not motion corrected). In each experiment, four sets of images were acquired: subject remains still, subject instructed to perform small movements during acquisition (simulating non-compliance), each acquired with and without PMC. Experiments were repeated for single-shot and segmented readouts. Images were acquired on a Siemens 3T Prisma system (Siemens Healthcare, Germany) using a 20 channel head/neck coil. PMC was performed using an in-bore optical camera. An external marker adhered to the forehead was tracked using moiré phase tracking (MPT). The pCASL labelling scheme used a 1800ms label duration, with a 1500ms post label delay. Pre saturation was implemented before labelling was performed. Background suppression by double inversion recovery was also employed. For the 3D GRASE readout, the parameters used were: TR/TE=5000/18ms; slices=24; matrix=48x64; bandwidth=2300 Hz/pixel; FOV=192x256mm^2; averages=3. The single shot readout used an ETL/EPI factor of 24/48, and the segmented approached was divided into four shots, each with ELT/EPI factor of 12/24. Offline using MevisLab (MeVis Medical Solutions, Bremen Germany), label/control image pairs were processed to produced perfusion weighted images.

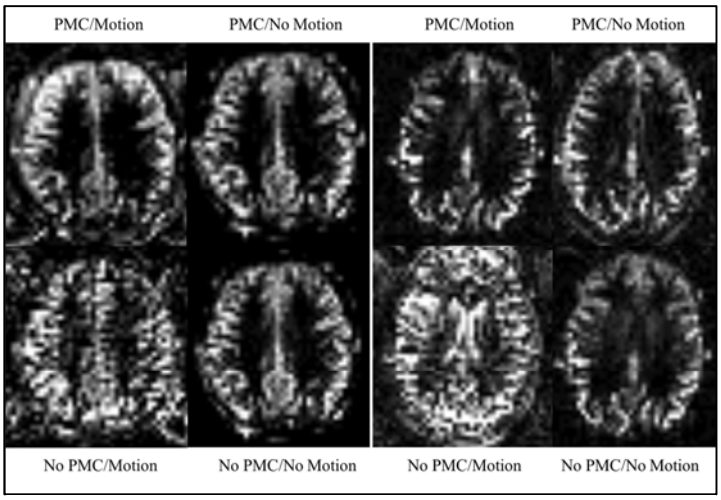

Figure 1: Example perfusion weighted images from two subjects acquired with the segmented GRASE readout. Images are acquired with and without PMC, and with and without motion.

Results: Resultant perfusion weighted images using a segmented readout can be seen in figure 1. In cases of subject motion, PMC can be seen to decrease motion induced artefacts. Even in the cases when subjects were asked to remain stationary, motion was still detected on the order of 1-2mm (approximately half a pixel), for example, as observed in the trace of Figure 2 (top row, X-translation). As a result, more subtle, but observable, improvements to the perfusion weighted images can be detected in compliant subjects when PMC is implemented.

Similar effectiveness of PMC was not observed for single shot acquisitions, as shown in figure 2. Although the control images display no observable differences with or without motion, subtraction artefacts are still observed.

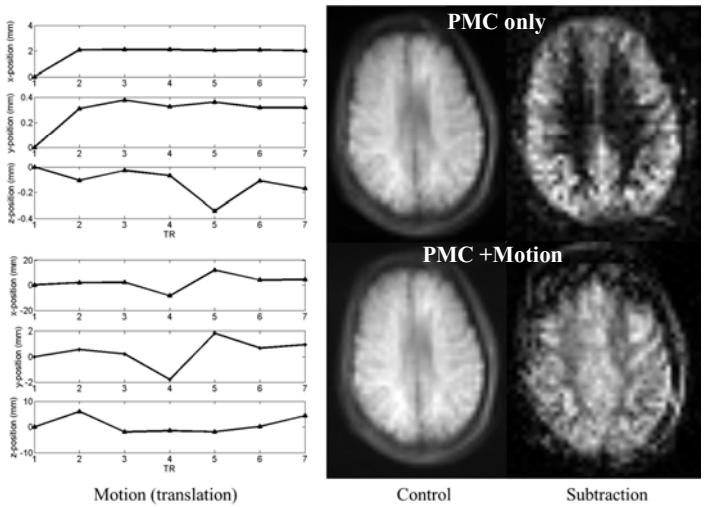

Figure 2: Example data from a single volunteer acquired with PMC, without (top row) and with (bottom row) motion. Measured translations, control images and perfusion weighted images are shown.

Discussions: The results highlight two potential sources of error regarding motion during ASL experiments. In the case of segmented imaging, PMC is observed to be an effective method in reducing object motion between segments, and thus producing subtraction images without misalignment. This improvement was not observed as robustly in single shot imaging. A likely reason for this is that motion during the GRASE readout is not corrected for. Phase errors and signal intensity changes, or changes in B_0 due to motion may have an effect on the perfusion weighted signal. It is therefore of interest to develop further an intra-readout correction. Another extension that would provide improvement would a correction of the pCASL labelling scheme. Labelling duration in this study was 1.8s in duration, and motion during this phase will also affect the perfusion weighted signal. This will also be more significant in the case of Hadamard encoding, where labelling times of multiple seconds can be achieved and several encoding steps are performed. Misalignment of the imaging and the labelling plane, which is assumed to be a constant distance apart, between the encoding steps, could be another potential source of error. As labelling occurs at the base of, or below the skull, it was assumed that motion was not as large as in the brain. Nevertheless, further studies are required to fully assess the impact of motion in this section of the head.

Conclusions: Prospective motion correction has been demonstrated to effectively supress motion induced errors in perfusion weighted images in the case of pCASL labelling with a segmented 3D GRASE readout. Improvements in perfusion weighted data can also be observed in the case of subject compliance. Further extensions to this study are however, required for the case of longer readouts and for the motion correction of the pCASL labelling scheme.

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References: [1] Alsop D.C et al. MRM 2014 0.1002/mrm.25197, [2] Fernandez-Seara MA et al. MRM 2005; 54(5), [3] Guenther M et al. MRM 2005; 54(2)