Pulsed Continuous Arterial Spin Labeling (PCASL) with Prospective Motion Correction (PROMO)

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INTRODUCTION The Pulsed Continuous Arterial Spin Labeling (PCASL) technique has been recently introduced to perform perfusion imaging [1]. It provides good properties such as high efficiency, 3D multi-slice capability and low hardware demands, which make itself a promising method for whole brain perfusion studies. However, a whole brain perfusion MRI protocol may suffer from long scan time with repeated acquisitions of both tagging and control images, and probably T1-weighted images as well for a quantitative study. Such a protocol would be vulnerable to patient motion. Therefore, it can be very beneficial to combine a 3D PCASL scan with prospective motion correction. PROspective MOtion (PROMO) correction [2-6] is a navigator-based technique which can be integrated into various pulse sequences to perform real-time motion estimation and correction. Here, we will demonstrate the feasibility of integrating a 3D PCASL sequence with a PROMO correction module. According to our preliminary results, with successful real-time correction, the robustness of the PCASL sequence can be significantly improved against brain motions. In the mean time, there would be little interference between perfusion images and PROMO navigators.

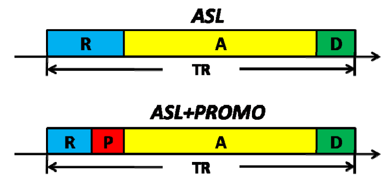

Figure 1: Timing diagram of PCASL and PCASL-PROMO. [R]-Recovery time; [A]-ASL preparation; [D]-Data acquisition (FSE, 3D stack-of-spirals); [P]- PROMO.

METHODS A timing diagram of our existing 3D PCASL sequence is briefly illustrated in Fig. 1. Each TR can be simply divided into three segments. During the ASL preparation time, a series of RF pulses may be applied to the brain with various purposes, including background suppression, perfusion tagging, or inversion recovery. Immediately after this, 3D acquisition is performed by using a fast-spin-echo (FSE) RF train and stack-of-spirals readouts. Finally, a recovery period is expected before the next preparation, which has been shifted to the beginning of TR in Fig. 1 for better illustration. By toggling preparation pulses, this timing structure applies to all scan passes including labeling, control, and reference image acquisition.

PROMO is a relatively independent module, in which 3-plane spiral navigator acquisitions, motion estimations, and imaging gradients/receiver adjustments (corrections) are all performed in real time by utilizing the dead time between different segments (TRs). All navigators are acquired with gradient echoes by using very small flip angles to reduce their influence to the imaging sequence. These properties make PROMO an ideal candidate for PCASL.

This PCASL-PROMO integration has been successfully implemented, as shown on the bottom of Fig. 1. The PROMO module is placed right before the preparation, occupying some recovery time. To simplify the implementation, the estimated motion parameters will not be applied to preparation and labeling pulses. In this case, we can avoid the challenges in dealing with non-linear RF pulses. This does not cause a large effect as the pulses are either non-selective or not applied to the imaging area.

In-vivo 3D experiments of PCASL-PROMO were performed on a 1.5T GE scanner for whole-brain perfusion imaging. The following parameters were used: TE/TR=5ms/6s; FOV=24cm; slice thickness=6mm; nslices=30; 8 spiral interleaves with a readout length of 512 (in-plane-res=3.5mm); NEX=3. Three scans were conducted on a healthy volunteer. In the first experiment (A), the subject tried to hold still. While in each of the latter ones, the subject produced a side-to-side motion during the scan, with PROMO correction switched on (B) and off (C), respectively. One scan requires about 6 min to acquire both labeling and control images.

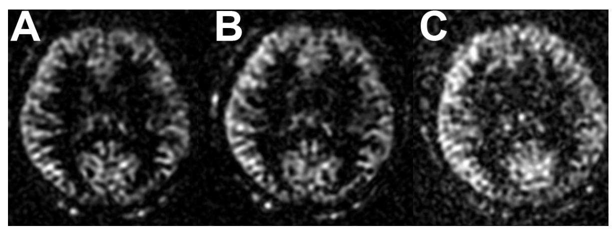

Figure 2: Perfusion weighted (difference) ASL images: (A) no motion; (B) motion with correction; (C) motion without correction.

RESULTS Images from three scans are compared in Fig 2. And the corresponding real-time motion estimates from the latter two are plotted in Fig 3. (PROMO motion tracking was enabled in the last scan, but these estimates were not applied for correction.) It shows similar degree of subject motions during these two scans. And this level of motion would cause severe signal loss in PCASL (Fig 3C). With real-time PROMO correction, motion artifacts can be greatly reduced (Fig 2B), yielding images with similar perfusion contrast as that of motion-free images (Fig 2A).

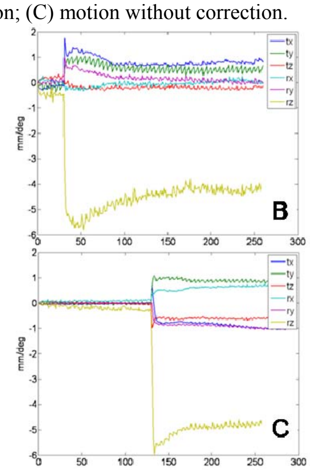

Figure 3: Motion plots of the last two scans (in mm /degree).

DISCUSSION AND CONCLUSION We have demonstrated an integration of 3D PCASL and PROMO in this work. With this implementation, PCASL-PROMO is very robust against patient motions during long perfusion scans without image artifacts due to the PROMO interference. This pulse sequence is expected to be tested on more patients and different magnetic field strengths and clinical scanners. Further improvements are also expected in the future. For examples, there is a fairly long post-correction period due to the ASL preparation (around 4sec). It is thus desirable to insert more PROMO navigators into the preparation stage to ensure that the performance of PROMO is not hampered if the motion occurs right after the initial PROMO correction. This would make the correction more effective by reducing the occurrence of corrupted acquisitions and PROMO rescans [3, 4]. Using variable-density spiral readouts in PCASL-PROMO will also help reduce the residual motion artifacts.

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