Achieving Late Inflow Delay in pseudo-CASL 3D GRASE Using a Hybridized Labeling and Background Suppression Scheme

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Introduction

We have previously demonstrated that an arterial spin labeling (ASL) sequence that combined pseudo-continuous ASL (pCASL) (1) with background suppressed single shot 3D GRASE (2) could be used to obtain perfusion maps in less than 1 min at 3T (3). The improved sequence had an approximate 6-fold sensitivity increase with respect to the commonly used CASL EPI (4), which allowed for a significant reduction in scan time. However the timing of the background suppression (BS) pulses that were placed before and after the pCASL pulse limited the duration of the labeling period as well as the post-labeling delay (PLD). The short PLD reduces the usefulness of the sequence in cases where the blood transit time is long, since it can lead to spurious CBF values in regions with prolonged arterial transit times as occurs in cerebro-vascular disease or acute stroke. Here we now present a modified version of this sequence that can be used to acquire perfusion maps with long PLD.

Materials and Methods

Studies were performed on a 3T Siemens Trio scanner using the product 8-channel head receiver array. Four healthy volunteers were scanned using the modified pCASL BS 3D GRASE (shown in Fig. 1). In order to have a long PLD and maintain the timing of the BS pulses, the pCASL pulse was broken in two segments and the first BS pulse was placed between the two. The duration of the two segments was varied for each PLD. In addition, to eliminate artifacts due to eddy currents generated by the unbalanced gradient waveform played during the labeling pulse, the polarity of the labeling gradients was reversed during the second half of each segment (see Fig. 2). Imaging parameters were: resolution=4x4x6 mm^3, FOV=250x196x96 mm^3, 16 nominal partitions with 13% oversampling, 5/8 partial Fourier, measured partitions=11, matrix size=64x49, BW=2790 Hz/pixel, gradient-echo spacing=0.4msec (with ramp sampling), spin-echo spacing=26msec, total read-out time=270msec, effective TE=52msec, refocusing flip angle=180° and TR=3.5 sec. The background suppression (BS) pulses were hyperbolic secant inversion pulses (15.35 msec duration and 220 mG RF amplitude) with inversion times of TI_1=1800 msec and TI_2=520 msec, respectively. Both pulses were non-selective. The pCASL pulse consisted of 1536 selective RF pulses, played sequentially, at equal spacing, for a 1.6 sec labeling duration. Each RF pulse was shaped as a Hanning window (peak B_1=53mG, duration=500 µsec and G=0.6 G/cm). For the control pulse, the RF phase alternated from 0 to 180°. Two scans were run, one with PLD=1200 msec, segment 1 duration=990 msec and segment 2 duration= 600 msecs and another one with PLD=1530 msec, segment 1 duration=1325 msec and segment 2 duration=265 msec. 20 perfusion images were obtained by subtraction of tag and control (after discarding 4 dummy scans) during a scan-time of 2.5 mins. Perfusion maps were generated by averaging the individual perfusion images.

Results and Discussion

Perfusion maps were successfully obtained in the four subjects (Fig. 3). Reversing the polarity of the label gradient waveform effectively eliminated artifacts due to eddy currents, as demonstrated by the negligible residual signal obtained in the subtraction of label and control acquired without RF (Fig. 3, bottom row). Gray matter SNR measured in the central slice of the perfusion maps was 7.4 ± 2.0 (mean ± standard deviation) for the 1200 PLD acquisitions and 6.6 ± 2.2 for the 1500 PLD maps. This preliminary study shows that perfusion maps with good image quality and sufficient SNR can be acquired using this sequence. Future work will involve quantitative evaluation of the labeling efficiency.

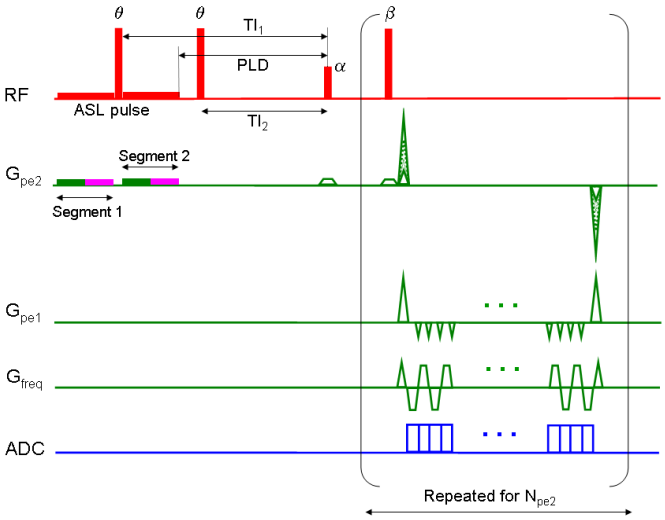

Figure 1: Pulse sequence diagram, showing the background suppression (θ) and pCASL pulses, added to the single shot 3D GRASE readout. The pCASL pulse was broken into two segments. The polarity of the gradient waveform was reversed during the second half of each segment (shown in pink, for details see Fig. 2).

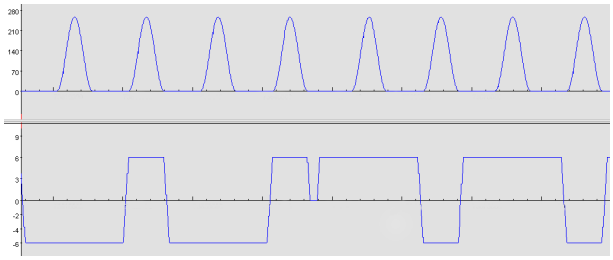

Figure 2: pCASL labeling pulse (RF and Gradient), showing the change in polarity of the gradient waveform, implemented in the middle of each pulse segment (transition from green to pink in Fig. 1).

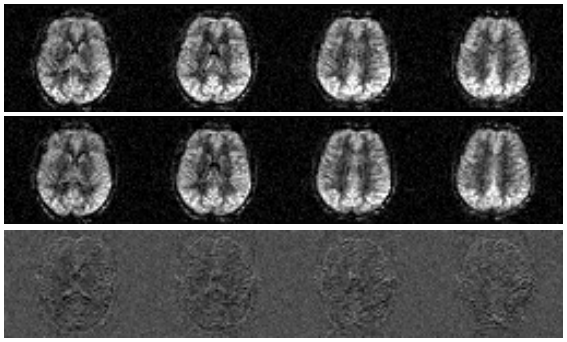

Figure 3: Perfusion maps obtained in a normal volunteer. Top row: 1200 msec PLD. Middle row: 1530 msec PLD. Bottom row: Subtraction of label and control images acquired with no RF.

Conclusions

A modified version of the pCASL BS 3D GRASE sequence has been implemented which allowed acquisition of perfusion maps with long post-labeling delay, in a short scan time. This sequence will be very useful in cases in which arterial transit time is expected to be long. The labeling scheme can be extended to arbitrarily long delay times, up to 3 seconds or longer with expected T_1 changes in sensitivity. We plan to evaluate this sequence in stroke, tumors and other pathological states.

Bibliography

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Acknowledgments: The authors would like to thank Dr. David Alsop for helpful discussions. NIH Grants: R44NS59223, P41-RR02305.