Influence of cardiac cycle on velocity selective arterial spin labeling

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Introduction

In brain perfusion measurements with Arterial Spin Labeling (ASL), blood is used as an endogenous tracer by inversion of the longitudinal magnetization of spins in blood. Two basic methods of inversion are available. In spatial selective labeling, as in pulsed- or continuous-ASL, the blood is tagged in an anatomical region at a certain distance proximal to the brain. Transit time that has to be allowed for the label to flow into the imaging plane has a drawback however; T1 relaxation of the labeled spins reduces sensitivity of the perfusion measurements and may pose problems in quantification. Pathologically prolonged transit time, for example in collateral circulation after ischemic stroke, may lead to significant loss of label and misinterpretation of perfusion measurements. As an alternative, velocity selective labeling can be applied. In this method, spatially nonselective pulses and gradients are applied to tag blood that flows faster than a predetermined cut-off velocity (v_c). In principle, this technique can deliver the label much closer to the imaging plane, reducing the error caused by T1 relaxation of the labeled spins significantly. However, because blood velocity is not constant, labeling efficiency may vary over the cardiac cycle. In this study we investigated whether label efficiency in velocity selective ASL is dependent of the timing of labeling relative to cardiac cycle.

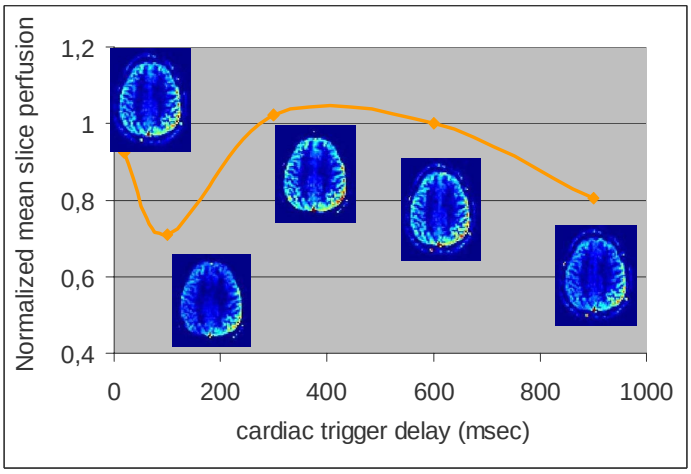

Figure 1a. Example of mean slice perfusion for evaluation slice. Data are normalized to mean perfusion at t_T = 600 msec. Depending on trigger delay, labeling efficiency varies. In this example mean perfusion dropped 20 to 30% for t_T = 900 and 100 ms resp., which can be recognized in perfusion images.

Materials and methods

Five healthy volunteers (4 male, 1 female) were scanned on a 3T, clinical scanner (Philips Medical Systems, The Netherlands). ASL was performed, applying a velocity selective spin labeling scheme that consisted of a double sech, spatially nonselective pulse train (1, 2). v_c was 2 cm/s, post labeling delay 1600 ms and inversion times for background suppression pulses were 50 and 1150 ms. The imaging module consisted of a single shot, GE-EPI sequence with TE 16 ms, TR 3800 ms with post imaging saturation, parallel imaging with SENSE factor 2.5 was applied and 50 dynamics were acquired. With a slice thickness/gap of 7/0 mm, 15 slices with an in-plane resolution of 3 x 3 mm^2 allowed for whole brain coverage. Prospective ECG triggering was used to determine the start of labeling. Different trigger delay times (t_T), i.e. time between R-peak of the ECG and trigger to start the labeling module, were chosen to cover the complete cardiac cycle. In four volunteers t_T in subsequent scans was set to 20, 100, 300, 600, 900 ms respectively. In one volunteer 6 scans were acquired with t_T of 20, 150, 300, 450, 600 and 750 ms. Average heart rate was 60 – 70 bpm. Perfusion images were generated through pair wise subtraction of control-label. Images were masked to exclude extra-cerebral voxels. For each slice, the mean slice perfusion was calculated as the numerical average of all pixel values within that slice. For comparison, mean slice perfusion was normalized to the value when trigger delay was set to t_T = 600 ms which represents cardiac diastole. The first slice superior to the ventricular system was chosen for evaluation.

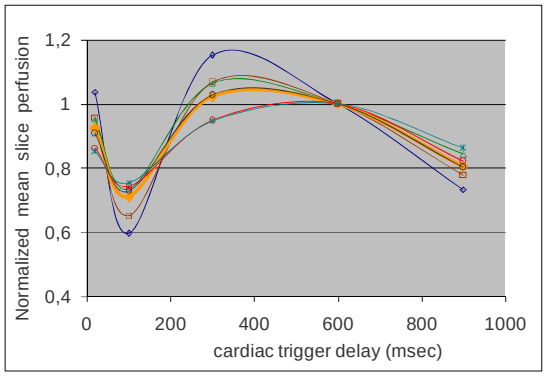

Figure 1b. Mean slice perfusion evaluation slice (orange line) and 3 inferior and superior slices within same subject as in figure 1a. All slices show variation of mean perfusion with trigger delay. Optimal delay time may differ between slices. (per slice, data are normalized to mean signal at t_T = 600 ms)

Results

For all trigger delay times good perfusion images where acquired, although some spatial variation in perfusion signal could be observed. In all volunteers the mean slice perfusion showed variation with t_T. Figure 1a gives an example of mean slice perfusion for different t_T, normalized to result for t_T = 600ms. In this example mean perfusion was approximately the same for a trigger delay of 20, 150 and 600 ms while mean signal dropped 20 – 30% with a delay of 900 and 150 ms resp. Within a single subject, the influence of trigger delay can be more or less pronounced between slices. This is illustrated in figure 1b that shows results for 3 adjacent slices, inferior and superior, to the evaluation slice. For this subject, maximum label efficiency was reached for t_T = 300 ms for all slices except for the upper three slices that showed higher signal for tT = 600ms.
The pattern of signal variation with trigger delay was found to vary between subjects. Figure 2 shows normalized mean perfusion in the evaluation slice of all subjects. Four subjects showed maximum label efficiency for t_T = 300 ms, for one subject t_T = 100 ms was optimal. Within each subject, a similar variation in mean slice perfusion was found, more or less pronounced, for all slices with exception of the 3 most cranial slices in two subjects.

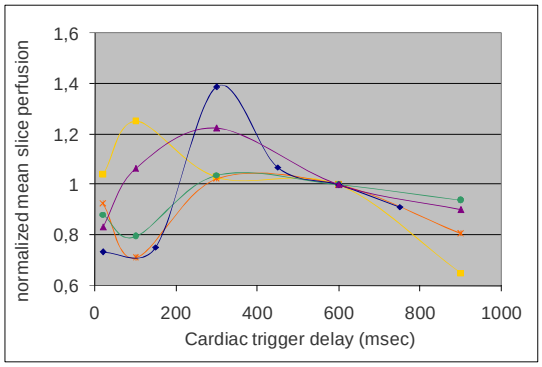

Figure 2. Mean slice perfusion for evaluation slices of all subjects. Subjects show different variation of mean label efficiency with trigger delay. Mean label efficiency may vary ± 20% relative to diastolic triggering. (Curves are normalized to mean perfusion at t_T = 600 ms).

Discussion and conclusion

In velocity selective ASL, mean labeling efficiency varies with the time point within the cardiac cycle that labeling is started. Label efficiency may vary ± 20% over cardiac cycle as compared to signal acquired with triggering during diastole. Without cardiac triggering this will result in loss of SNR due to physiological noise. When cardiac triggering is applied, a trigger delay of 300 ms gives highest label efficiency in most cases. At higher heart rates percentage of variation in label efficiency in VS-ASL and optimal trigger delay may be different and needs to be investigated further.

References

1. Wong et al. Proc ISMRM 11, Honolulu, 2002 p 621
2. Duhamel et al. Magn. Reson. Med. 50:145-153 (2003)