SSFP Arterial Spin Labeling Myocardial Perfusion Imaging at 3 Tesla

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Introduction: Arterial spin labeling MRI at 3T, as compared to imaging at 1.5 T, in principle, gains from the longer T1 and increased signal-to-noise ratio (SNR) for improved labeling and detection of inflowing arterial spins. In the current work, we investigated the potential and drawbacks of using an arterial spin labeling (ASL) SSFP imaging sequence at such field strength for quantitative mapping of myocardial perfusion.

Methods: Seven healthy volunteers were studied on a 3T whole body MR scanner (Magnetom Trio, Siemens, AG). A cardiac triggered, segmented SSFP (true FISP) sequence was combined with a FAIR [1-2] spin labeling technique, in which slice-selective and slice-nonselective inversion pulses were applied alternately to generate two sets of images (control and label) in a 16-20 sec breath-hold scan. Inversion pulses were applied every other heart beat. Inversion time TI was set to one R-R interval to ensure images are acquired at the same cardiac phase as that of the inversion pulses. An 8-element cardiac coil array was used in these experiments. Imaging parameters were: TR/TE = 3.0ms/1.1ms, section thickness = 10-12 mm, matrix size = 128-192 x 128-192 and FOV = 28 -35 cm. For flow quantification purpose, eleven additional images were also acquired at different TIs. T1 and equilibrium magnetization M_0 were then extracted using the following equation:

$$M(\mathrm{TI}) = M_0 \frac{\left[1-\exp\left(-\mathrm{TI}/\mathrm{T}_1\right)\right]-\alpha\left[\exp\left(-\mathrm{TI}/\mathrm{T}_1\right)-\exp\left(-\tau/T_1\right)\right]}{1+\alpha\exp\left(-\tau/T_1\right)} \qquad (1)$$

where M(TI) is the tissue magnetization at inversion time TI, τ is the time between inversion pulses, and α represents the effect of an imperfect inversion (α = 1 for complete inversion). Assuming T1 of the myocardium is the same as that of the blood, perfusion f can then be calculated as [3]

$$f = \left(\frac{\Delta M}{M_0}\right)\cdot\left(\frac{\lambda}{TI}\right)\cdot\left(\frac{1+\alpha\exp\left(-\tau/T_1\right)}{(1+\alpha)\exp\left(-\mathrm{TI}/\mathrm{T}_1\right)}\right) \qquad (2)$$

where λ is the blood/tissue water partition coefficient, ΔM is the difference of magnetization between control and labeled images, and M_0 is the equilibrium magnetization.

Results: Using standard global shim, banding artifacts caused by off-resonance are routinely seen in the ASL SSFP images obtained at 3T, particularly near the heart-lung boundary. Figure 1 shows such an example, in which severe banding artifacts are observed in the anterior wall of the left ventricle (arrows, Fig 1A and B). The artifacts can be reduced or eliminated by performing a localized shim in a region centered on the heart, as demonstrated in Fig 1D and E. Flow weighted images calculated as the difference between control and label images are displayed in Fig 1C and F, demonstrating the feasibility of the current technique for obtaining myocardial perfusion information.

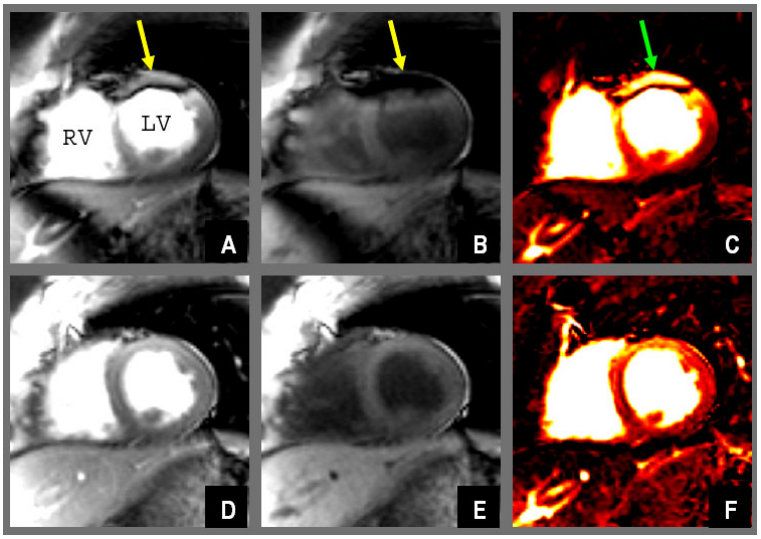

Figure 1. A)-C) Images obtained from a healthy subject at 3T without localized shim showing off-resonance banding artifacts (arrows) associated with SSFP imaging. D)-F) The banding artifacts were eliminated after performing localized shim.

To quantify myocardial perfusion, additional data were acquired for estimate of T1 and M_0. One example is shown in Figure 2, in which T1 and M_0 were obtained by fitting experiment data using Equation 1. Regional blood flow can then be calculated using Equation 2. For example, f = 2.7 ml/mg/min was obtained in one subject using the following data: ΔM = 20, M_0 = 636, TI = 900 ms, and τ = 1.7 sec.

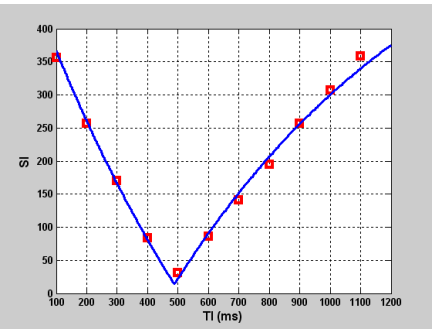

Figure 2. T1 relaxation of LV myocardium following slice non-selective inversion.

Discussion: ASL perfusion MRI offers the advantages of high spatial resolution and does not require contrast injections. However, this technique is generally limited by low SNR. With increased SNR and longer T1 at 3T, significant improvement in the labeling and detection of arterial inflowing spins is expected. Using a SSFP ASL imaging sequence, we have investigated the feasibility of realizing such improvement. Problems such as off-resonance artifacts associated with SSFP imaging are particularly challenging at 3T, which must be eliminated before the SSFP ASL technique can be used at this filed strength. Further studies are required to determine whether ASL myocardial perfusion imaging at 3T is indeed advantageous.

References

1. Kwong KK, et al. MRM 1995;34:878-887. **2.** Kim SG. MRM 1995;34:293-301. **3.** An J, et al. Proc. ISMRM 2004, p 316.