Feasibility of Remote Polarization for Angiography Using Prepolarized MRI

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Introduction

Using a prepolarized MRI scanner, with its polarizing magnet removed from the homogeneous acquisition region (figure 1), we investigated remote polarization as a contrast method for angiography. A Prepolarized MRI scanner pulses two resistive electromagnets magnets instead of one superconducting magnet: the "polarizer" makes a strong, relatively inhomogeneous field (0.4-1.0T) to create spin polarization, and the "readout" creates a stable, homogeneous field (25-100mT) for MR signal acquisition [1]. The primary advantage is the relatively low-cost of the resistive magnets, because careful execution enables SNR at the polarizing field strength.

Another advantage of this system is the possibility of physically separating the polarizer and readout magnets. Recent work with hyper-polarized gas MRI has led to several techniques which take advantage of the separation between polarization and acquisition [2]. This feasibility study is similar in concept to that of arterial spin labeling [3], or most other in-flow techniques. By limiting spin magnetization to a region upstream of the ROI, only those spins within vessels will provide MR signal after the prescribed waiting time.

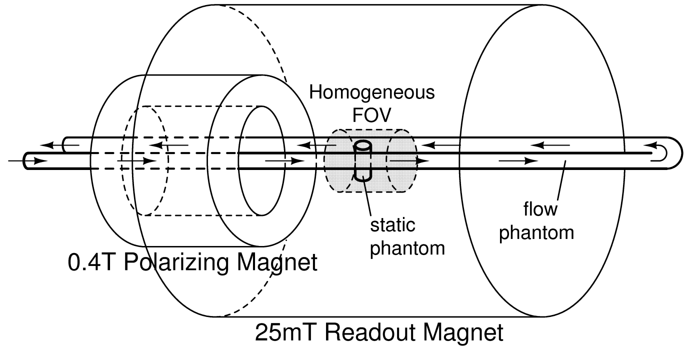

Figure 1: Experimental Setup. 0.4T polarizing magnet is offset from 25mT Readout magnet's central, homogeneous FOV. Polarized spins (as from a vessel) flow into the FOV for imaging. Static material in the ROI is only weakly polarized, so it gives very low MR signal.

Methods

We made a flow phantom, to mimic the MR behavior of blood in the brachial artery at the 1MHz Larmor frequency (T_1=300ms), using a peristaltic, constant flow pump (Cole-Parmer, Vernon Hills, IL) at 20cm/s mean flow rate. The vessel goes down and comes back through the ROI (figure 1) and around a static vial with adipose (T_1=100ms) MR properties.

To combat readout field inhomogeneity, we used a spin-echo pulse sequence (TE = 6-20ms, 6-8cm FOV, 2DFT projections). All gradients follow the 180 pulse to minimize flow moments. Finally, we made the readout perpendicular to the direction of flow to avoid dephasing signal loss.

Results

Figure 2 shows the acquired proof-of-concept projections. The top two images (a,b) are from the standard PMRI setup with the polarizing coil centered on the FOV. Figure 2(a) is a reference image of the phantom without flow (64x64, 8cm2 FOV, 2DFT, TR=1s). Due to flow-related losses, we lowered TE and increased voxel size to acquire images (b) and (c) (32x32, 6cm FOV, 2DFT, TR=1s) with 20cm/s vessel flow. Image (c) was acquired by remotely polarizing 6-26cm from the ROI. This image, while low-SNR, shows far less signal in the retrograde and static samples, and far more signal in the forward-flowing tube.

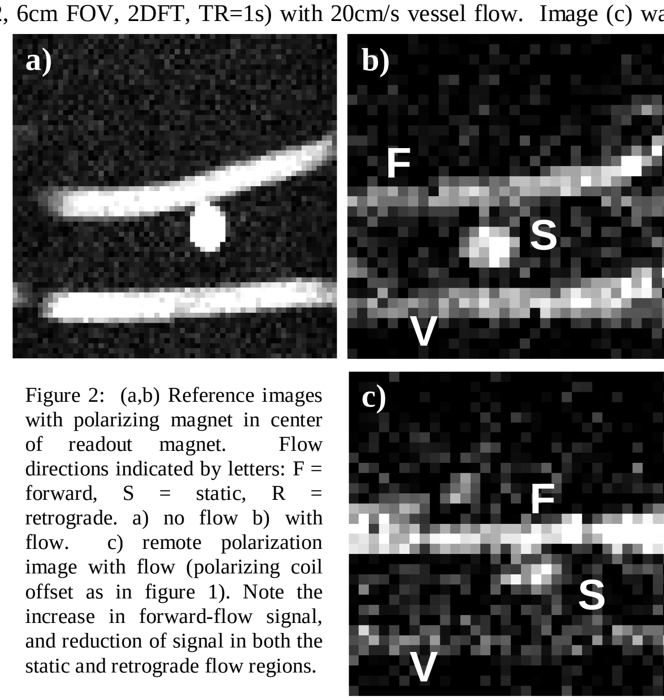

Figure 2: (a,b) Reference images with polarizing magnet in center of readout magnet. Flow directions indicated by letters: F = forward, S = static, R = retrograde. a) no flow b) with flow. c) remote polarization image with flow (polarizing coil offset as in figure 1). Note the increase in forward-flow signal, and reduction of signal in both the static and retrograde flow regions.

Discussion

Several facets of this work must come together if this technique is to be successful. First, the images with flow display an unresolved tradeoff between flow-related artifact reduction and SNR maintenance. We expect further sequence development will allow for efficient flow compensation and increased SNR and CNR. Also, the T_2 in our phantom nearly equals T_1, which is not true in vivo unless the material passes through a region of zero field. By holding some static field on the spins (in this case, the readout field), T_1 decay between the polarization and acquisition intervals should dominate T_2 effects. Finally, arterial flow is tri-phased, not constant. We expect this will improve the performance of this method—given gating—because with tri-phased flow there are longer, static intervals for both polarizing and reading out, with punctuated transit times into the ROI.

Conclusion

It is unclear whether the contrast to noise ratio of this method will be able to compete with current techniques. The data presented here confirms that remote polarization can create contrast with constant flow rates. Further investigation with pulsatile flow phantoms, and further development of flow-robust sequences are necessary to validate this as a method for extremity angiography.

References

[1] Morgan, P. et al, MRM 1996, 36(4): 527-536.
[2] Moule, A. et al, PNAS 2003, 100(16): 9122-9127.
[3] Williams, D. et al, PNAS 1992, 89(1): 212-216.