**Non-Contrast-Enhanced SSFP MRA with Improved Consistency and Fluid Suppression**

Y. Jung[1], A. Lu[2], T. M. Grist[3,4], W. F. Block[2,4]
[1]Electrical and Computer Engineering, UW-Madison, Madison, WI, United States, [2]Biomedical Engineering, UW-Madison, Madison, WI, United States, [3]Radiology, UW-Madison, Madison, WI, United States, [4]Medical Physics, UW-Madison, Madison, WI, United States

## INTRODUCTION

Excellent non-contrast-enhanced MRA of the carotid and peripheral arteries has been achieved with the SSFP implementation of the 3DPR sequence known as VIPR [1]. The sequence is robust to motion artefacts and provides excellent fat suppression achieved using the Linear Combination SSFP (LC SSFP) method [2]. However, cerebral spinal fluid (CSF) and joint fluid have higher $T_2/T_1$ ratios than arterial blood and thus produce bright signal that can obscure visualization of the vasculature. Additionally, carotid arterial signal levels have been inconsistent due to $B_0$ field inhomogeneity from the air/tissue interface in the neck. In this work, an inversion recovery (IR) technique [3] has been modified for SSFP VIPR to attenuate unwanted fluid signals. To improve consistency, we acquire a fast field map in the plane of the carotid arteries and adjust the demodulation frequency and linear shim terms accordingly. These improvements require a small increment in scan time but produce a large increase in image quality.

## MATERIALS AND METHODS

Effective shimming with phased array neurovascular coils is difficult due to the large number of air/tissue interfaces near the head and shoulders. Previously we had more consistent results using a head coil with less coverage in the neck.

A fast gradient recalled sequence was modified to obtain two images with a 1 ms delay in echo time. The images were acquired in the plane of the carotid arteries. A field map was produced and used to calculate the optimal resonance frequency and linear shim terms for the arterial signal.

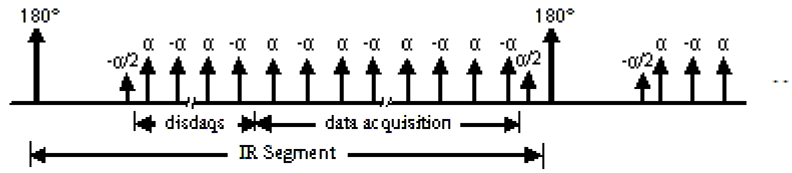


**Figure 1.** *RF pulse schedule for the inversion recovery data acquisition*

A magnetization-prepared IR technique [4] was implemented to attenuate the undesired fluid signals that recover more slowly than blood due to their long $T_1$ values. The timing of RF pulses for the IR implementation is shown in Figure 1. Following the non-slice selective inversion pulse, a simple catalyzation technique is used to reduce oscillations in the transition to the SSFP steady-state [5]. The last $\alpha/2$ pulse in an IR segment is employed to restore the remaining transverse magnetization to the longitudinal axis. Data acquisition does not begin until approximately 1 s after the inversion pulse to avoid sampling inverted arterial signal. After that interval, blood is significantly recovered while undesired fluid signals are passing through a recovery null. In Cartesian imaging, the central phase encodings can be ordered to occur during this null. Since the center of k-space is acquired in each TR with 3DPR, a density compensation technique was implemented to emphasize the oversampled central spatial frequencies acquired when undesired fluids are nulled. The temporal filter width varies with the radial k-space dimension to satisfy the Nyquist criteria, as shown in Figure 2. Projection directions are scrambled during each recovery period scan so that spatial frequency directions are not correlated with the signal recovery. The scheduling of projection directions is also interleaved to reduce motion artifacts.

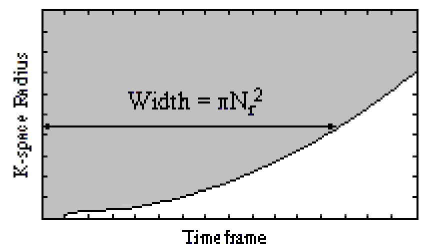


**Figure 2.** *Temporal filter design (The shaded area in k-space is utilized for the reconstruction)*

## RESULTS AND DISCUSSION

All experiments were executed on 1.5T Signa Advantage scanner with an 8-channel neurovascular coil (GE Healthcare, Milwaukee, WI). A dual-half-echo VIPR sequence [6] was used with scan parameters of 2.5 ms TR, 30° flip angle, 24cm FOV, 256 readouts, ±125 kHz RBW, 32,000 projections, 16 IR segments, and 16 timeframes in each IR segment. All reconstructed images have 0.94 mm 3D isotropic resolution. The scan time for LC SSFP was 160 s and IR VIPR was 185 s. Figure 3a, 3b, and 3c shows a magnified thin MIP reformat of the left carotid artery using the LC SSFP without IR preparation. The image before the field map correction is shown in Figure 3a. The field map correction allows consistently higher arterial signal from the inferior edge of the scan slab to the base of the brain, as shown in Figure 3b and 3c. Using the IR prepared VIPR sequence, CSF was significantly suppressed as shown in the similar perspective in Figure 3d. Approximately 40% of signal loss in blood was measured due to its recovery from the magnetization preparation and the applied temporal filtering.

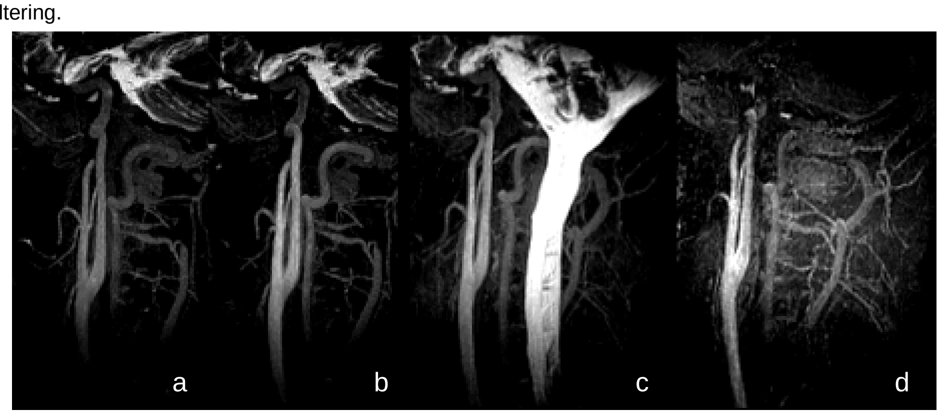


**Figure 3.** *Partial MIP images of left carotid artery before (a) and after (b, c) the field map correction and CSF suppressed image from IR VIPR sequence (d)*

## CONCLUSIONS

Our initial results show that targeting shimming provides stronger vascular signal over a larger FOV using neurovascular phased-array coil. Non-contrast-enhanced angio-graphy with unwanted fluid suppression, fat suppression, and isotropic resolution have been demonstrate with a tolerable increase in scan time over our previous method.

## REFERENCES

**1.** Lu A, *et al*., *JMRI,* **19**, 117, 2004.
**2**. Vasanawala SS, *et al., MRM* **43**, 82, 2000.
**3.** Bangerter NK, *et al*., *Proc. Twelfth ISMRM,* 11, 2004.
**4.** Scheffler K, *et al*., *MRM,* **45,** 720, 2001.
**5.** Deimling M, *et al*., *Proc. SMR,* 495, 1994.
**6.** Lu A, *et al*., *Proc. Eleventh ISMRM,* 320, 2003.