Low Power Adiabatic Inversion for Arterial Spin Labeling

Ovidiu Cristian Andronesi[1], Uvo C. Hoelscher[2], Himanshu Bhat[3], Keith Heberlein[3], and Bruce R. Rosen[1]

[1]Martinos Center for Biomedical Imaging, Department of Radiology, Massachusetts General Hospital, Harvard Medical School, Boston, MA, United States, [2]Siemens Healthcare, AG, Erlangen, Bayern, Germany, [3]Siemens Healthcare USA, Boston, MA, United States

Target Audience: Neuroradiologists, neurologists, neuroscientists interested in brain perfusion; developers of pulse sequences for blood perfusion.

Purpose. Arterial spin labeling (ASL) [1] provides a completely non-invasive method to measure blood perfusion and vascular territories, and in certain cases may be the only technique that provides this information when contrast agents cannot be administered due to clinical reasons. Adequate SNR is critical for the ASL methods, and inversion of magnetization of the blood spins is a main factor responsible for the SNR in ASL. With the ongoing trend in the development of MR hardware towards large-bore scanners and the active control of the RFPA duty cycle there is an increased need for efficient and low-power adiabatic inversion. Here we present the use of Gradient Offset Independent Adiabaticity GOIA-W(16,4) [2] pulses for low power adiabatic tagging of blood in ASL sequences.

Methods. Pulse sequences were implemented on Magnetom Skyra 3T scanners (Siemens AG, Erlangen, Germany) running IDEA VD13C software. The RF transmit chain is based on the TIM 4G platform which includes a real-time system to control the RFPA duty cycle based on the energy available in the amplifier and the power that needs to be delivered for a certain coil load. A 32-channel head coil was used for receive. A 3D ASL sequence based on FAIR [3] tagging with GRASE [4] image readout was used to acquire perfusion maps at 3 mm isotropic, 64x64x40 matrix, in 2:05 min (TR=5000ms, TE=16.8ms, TI1=700ms, TI2=1990ms). In particular, we investigated the performance of two GOIA-W(16,4) [2] pulses of: i) 10 ms duration, 20 kHz bandwidth, 500 Hz B_{1max}, and ii) 5 ms, 30 kHz bandwidth and 840 Hz B_{1max}. We compared the labeling efficiency of these GOIA-W(16,4) pulses with that of the FOCI [5] pulse of 10 ms duration, 20kHz bandwidth, and 870 Hz B_{1max}.

Results. We tested our sequences in an agar phantom and five healthy volunteers with informed consent. The FOCI pulses require the largest transmit power, and with the real-time control of RFPA power its B_{1max} may be derated by a variable amount depending on the subject. Simulations of the slice profiles (Fig.1) indicate that derating reduces the inversion of FOCI in the middle of the slab. GOIA pulses require only half of the B_{1max} of the FOCI pulses, and their amplitude is not reduced. On contrary, the B_{1max} of GOIA pulses can be increased by 20% allowing to compensate for B_1 inhomogeneity. Perfusion maps obtained in human brain show that SNR is improved overall with GOIA pulses. Largest SNR gain (50%) is noticed especially in the middle of the brain as expected from simulations.

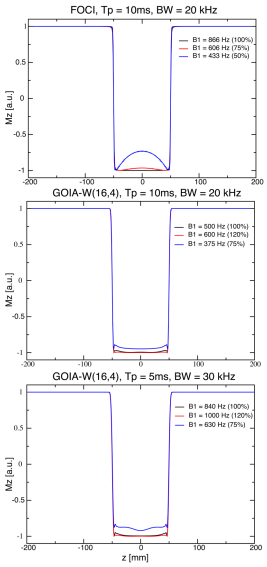

Figure 1. Slice profiles of FOCI and GOIA-W(16,4) pulses. B_{1max} of GOIA-W(16,4) can be increased on the scanner and simulations were done above (120%, red) and below (75%, blue) the adiabatic threshold (100%, black). For FOCI pulses the B_{1max} cannot be increased, and simulations were done for 75% (red) and 50% (blue) compared to the adiabatic threshold (100%, black).

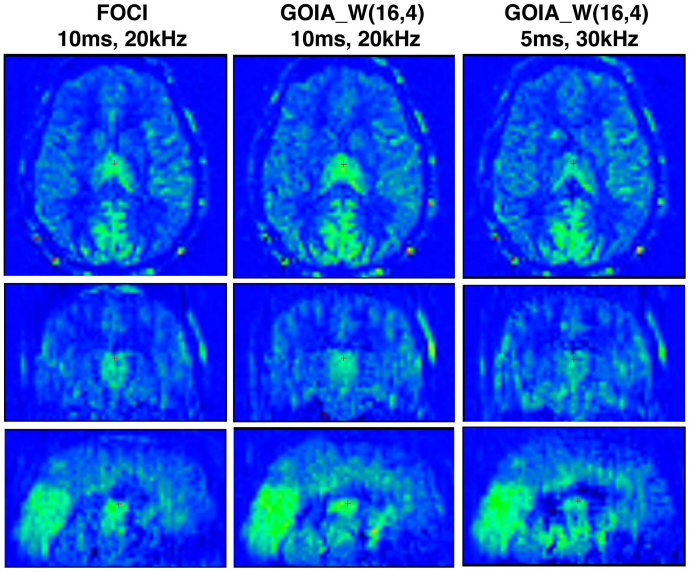

Figure 2. Perfusion maps obtained with different ASL tagging. GOIA pulses provide overall more SNR, the largest gain is observed especially in the middle of the brain. All perfusion maps are scaled to the same image intensity.

Discussions/Conclusion. GOIA-W(16,4) pulses provide efficient inversion under low power conditions. The improved inversion increases the SNR in ASL sequences. The maximum B1 amplitude of GOIA-W(16,4) pulse can be raised above the adiabatic threshold within the limits of the RFPA duty cycle which provides a way to compensate for B1 inhomogeneity. This might be even more beneficial for applications in the body were inhomogeneity in B1 is greater than in the head. Further validation and testing is underway.

References: [1] Detre et al, MRM 1992, 23:37-45; [2] Andronesi et al, JMR 2010, 203:283-93; [3] Kim, MRM 1995, 34:293–301; [4] Gunther et al, MRM 2005, 54:491-8; [5] Ordidge et al, MRM 1996, 36:562–66. **Acknowledgments:** funding from 1K22CA178269-01 (NCI/NIH), support from W. Bogner and R. Neji.