Perfusion and Flow Measurement in Human Brain by Pseudo Random Amplitude Modulation (PRAM) in 3T MRI

M. R. Taei-Tehrani[1,2], and T. R. Brown[1,2]

[1]Radiology Department, Columbia University, New York, New York, United States, [2]Biomedical Engineering Department, Columbia University, New York, New York, United States

Introduction: Absolute measurement of cerebral blood flow and brain perfusion in MRI is of great importance in early diagnoses of diseases such as stroke, dementia, or even tumor detection. We present here a new method based on pseudo random inversion of inflowing blood. The proposed Pseudo Random Arterial Modulation (PRAM) method uses water as a tracer to measure absolute blood flow and acquires transit times within one integrated scan. The PRAM method does not require separate control and label acquisitions, but rather mixes them according to the specific pseudo random sequence used.

Theory: PRAM is based on a cyclical application of a pseudo random sequence of inversions and non-inversions of the arterial water at the labeling plane. To accomplish this, an adiabatic inversion or non-inversion pre-pulse (PRAM pulse) [1] is performed prior to gradient echo sequence (Figure 1).The magnetization in the imaging plane, at a distance from labeling plane, is then modulated based on the temporally delayed PRAM pulse. Thus, the magnetization signal at time t_i, denoted by $M_a(t_i)$, is the sum over all the transient times in $M_a(t_i)=\sum_j P_{i-j}\times F(t_j)$, where $F(t_j)$ is the fraction of the arterial spins that takes t_j to travel from the labeling plane to the image plane and the PRAM modulation sequence, P_i is such that $P_i=-1$ if the pre-pulse is 180^o inversion pulse or $P_i=1$ for non-inversion. Since the modulation sequence P_{i-j} is known, $F(t_j)$ can be calculated for each transit time by inverting P.

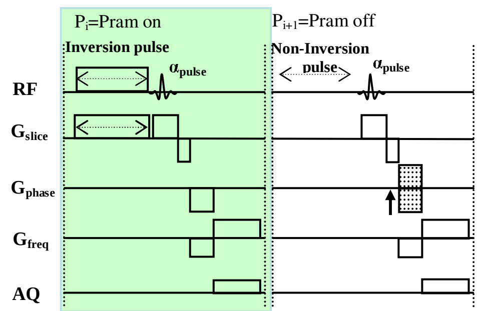

Figure 1. Pram pulse sequence diagram

Methods: PRAM data were acquired on a Philips Achieva 3T MRI scanner. The inversion plane was located 30 mm from the middle of the imaging slice for the flow phantom (2.54 cm i.d.) and 80 mm inferior to the imaging plane in the volunteer. Each TR, the RF pre-pulse was 180^o adiabatic inversion pulse or a delay of equal duration to generate a non-inversion pulse, based on 7, 15, 31, or 63 pseudo-random binary sequences. The images were acquired with 90^o flip angle, matrix size of 64x64, 5 mm slice thickness, and with FOV of 192mm and TR of 300ms for the brain and with FOV of 64mm and TR of 500ms for the flow phantom.

Results: The PRAM reconstructed images for the first 8 transit times are shown in Figure 2. By measuring the transit time from the middle of PRAM pulse, we expect the maximum velocity in the flow phantom of 4.35cc/s (V_{max}=1.72cm/s) to appear at 1747ms. This corresponds to what is seen in Figure 2a at t=(n-1)*TR+TR/2=1750ms or the maximum measured velocity of 1.71cm/s in the fourth image. For Poiseuille flow, the radial velocity distribution is quadratic; implying that square of the radius of the visible ring should vary inversely with transit time (Figure 3). In the human brain, the Left Vertebral Artery (LVA) flow appears at n=4 corresponding to a velocity of around 7.6 cm/s. The blood velocity of Right Inner Carotid Artery (RICA) and Left Inner Carotid Artery (LICA) appear in n=2 in Figure 2b indicating they have similar velocities of 18 cm/s.

Discussion & Conclusion: Initial application of PRAM to the brain measured average velocities in the arteries and veins. Although here only one imaging slice was acquired to simplify the pulse programming, the extension of PRAM to multi-slice acquisition is straightforward and will provide a 3D view of the velocities. PRAM can measure flow distributions, acquiring the range of transit times in the subject. It was tested on phantoms as well as on human subjects with results in agreement with Poiseuille flow calculations.

References: [1] DC Alsop, JA Detre, "Multi section cerebral blood flow MR…", Radiology, 208, 410–416, 1998.

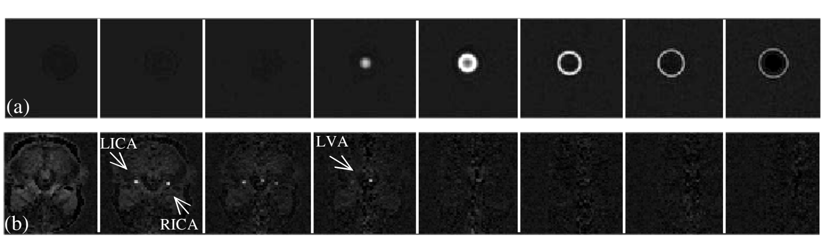

Figure 2. The first 8 Pram reconstructed images with the pram acquisition of 15. (a) Flow phantom with TR of 500ms, Labeling offset 30mm and Flow of 4.35cc/sec. (b) Human brain with TR of 300ms and Labeling offset=80mm. LICA. RICA and LVA arteries are shown.

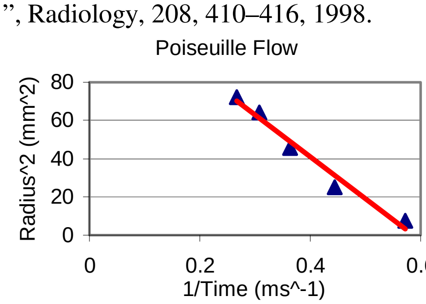

Figure 3. The flow phantom has Poiseuille flow and therefore t^{-1} is linearly proportional to r^2.