A new ASL scheme of repeated labeling based on FAIR sequence

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INTRODUCTION: Flow-sensitive alternating inversion recovery (FAIR) is a means of MR perfusion to assess cerebral blood flow based on arterial spin labeling (1). Since FAIR uses only a single inversion pulse for labeling, the signal-to-noise ratio (SNR) is restricted. The short duration for inflowing labeled spins limits the exchange time between tissue and vasculature. Hence, the image tends to be influenced by labeled spins located in vessels. The purpose of this study was to develop a new pulse sequence (multi-inversion FAIR) that utilizes serial inversion pulses for labeling blood to obtain a higher SNR of images than conventional FAIR images.

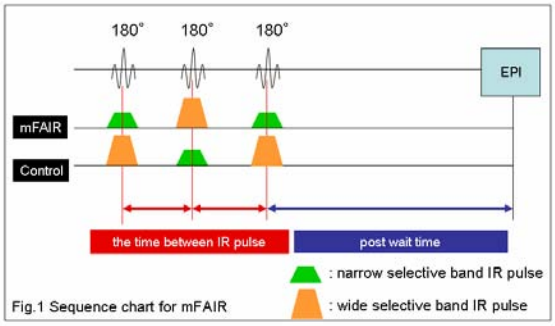


Fig.1 Sequence chart for mFAIR

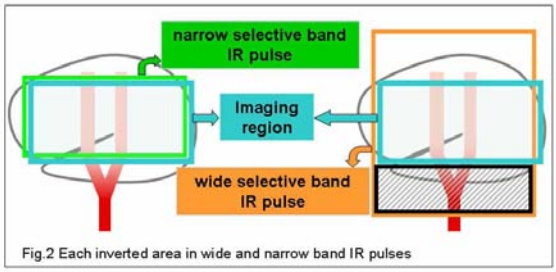


Fig.2 Each inverted area in wide and narrow band IR pulses

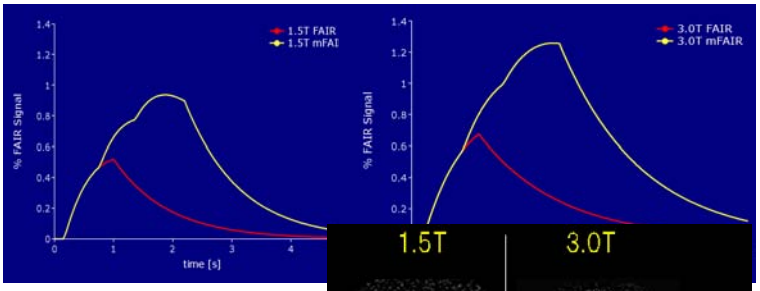
THEORY: Figure 1 shows the sequence chart for multi-inversion FAIR (mFAIR), which consisted of multiple 180 pulses for labeling and EPI acquisition. Just after the 2nd inversion pulse with a wide selective band, the spins in vasculature located in the labeling band between the narrow and wide selective areas (shaded region in Figure 2) were inverted, while the spins in the imaging region reverted to the original direction; therefore, the spin-labeling effect continued in the second inversion period. Since inflowing spins are kept opposite to the original spin direction in the imaging slab in the each inversion period, we can obtain continuous labeling effect in the later inversion periods. Control scans were also acquired using 180 pulses with the opposite selective band width, in which spins remained in the same direction as the original tissue spins (Figure 1). Perfusion weighted images were obtained by subtracting a control image from a labeled image. A perfusion signal was simulated by the single compartment model, which is described in the modified Bloch equation. The equation solutions are summarized in Eq.1 as follows

$$y(t)=\frac{2fM_0}{\lambda}\cdot\frac{1}{\frac{1}{T_{1app}}-\frac{1}{T_{1a}}}\cdot\exp\left(-\frac{\delta_a}{T_{1a}}\right)\cdot\exp\left(-\frac{t}{T_{1a}}-\frac{t}{T_{1app}}\right)\qquad 0<t\le t_1$$

$$y(t)=\exp\left(-\frac{t}{T_{1app}}\right)\cdot\left[\frac{2fM_0}{\lambda}\cdot\frac{1}{\frac{1}{T_{1app}}-\frac{1}{T_{1a}}}\cdot\exp\left(-\frac{\delta_a}{T_{1a}}\right)\cdot\left[\exp\left(\frac{1}{T_{1app}}-\frac{1}{T_{1a}}\right)t-1\right]+y(t_1)\right]\qquad t_1<t\le t_2$$

$$y(t)=\exp\left(-\frac{t}{T_{1app}}\right)\cdot\left[\frac{2fM_0}{\lambda}\cdot\frac{1}{\frac{1}{T_{1app}}-\frac{1}{T_{1a}}}\cdot\exp\left(-\frac{\delta_a}{T_{1a}}\right)\cdot\left[\exp\left(\frac{1}{T_{1app}}-\frac{1}{T_{1a}}\right)t-1\right]+y(t_1)\right]\qquad t_1<t\le t_2$$

where M_0: the equilibrium value of magnetization, Ma: z magnetization of arterial vessel, α: inversion efficiency, λ: blood partition coefficient of tissue water ratio, δ: transit time between label and imaging plane, T1app, T1a: longitudinal time of apparent tissue and blood, respectively, f: blood flow.



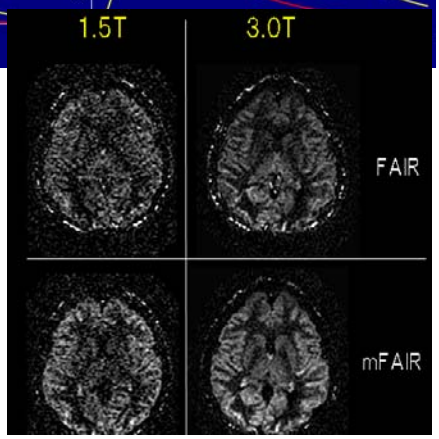


Fig.3 Perfusion images

METHODS: The imaging sequence was implemented on a 1.5T and 3.0T MR system; Signa Excite HD (GE, Milwaukee, USA) with an 8-channel phase array head coil. Both FAIR and mFAIR images were compared in both magnetic fields. The perfusion signal was calculated using Eq. 1 in the previous section. FAIR and mFAIR were obtained in 5 normal subjects by each MR system. The SNR of the perfusion images was measured in MCA territory on each image.

RESULTS and DISCUSSION: In signal simulations, high field FAIR is appealing because it provides not only increased SNR, but also advantages in terms of labeling due to the increased relaxation time T1 of labeled blood. Perfusion images with mFAIR are shown on Figure 3. The perfusion signal was apparently increased along with the number of 180 pulses. SNR of FAIR (1.5T), mFAIR (1.5T), FAIR (3T) and mFAIR (3T) were 1.42, 2.60, 2.67 and 4.46, respectively. SNR was significantly improved in mFAIR compared with FAIR: moreover, the increase of SNR was larger in 3T than 1.5T. mFAIR is easy to implement on an MR scanner since SAR is still well be of low the FDA limit. In conclusion, the mFAIR sequence provides an efficient labeling scheme for ASL imaging with improved SNR compared with conventional FAIR.

REFERENCES:1. S.G.Kim et al. Magn. Reson. Med. 34:293-301;1995, 2. Calamante F et al. NMR Biomed 9:79-83;1996