Improved SNR using complex subtraction in flow-sensitive alternating recovery (FAIR)

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Introduction: Arterial spin labeling perfusion imaging generates images where contrast results from the amount of inflowing blood to each pixel. Due to the relatively small blood volume fraction in regions such as the brain, such techniques typically have poor SNR. In addition the contrast generating signal comes from vessels which are generally significantly smaller than the imaging resolution, resulting in significant partial volume effects. In the flow-sensitive alternating inversion recovery (FAIR) spin labeling technique [1] two consecutive acquisitions, one with a non-selective inversion preparation and one with a selective inversion preparation are subtracted. In subtraction techniques that suffer from partial voluming it is known that there are advantages to performing a complex subtraction on the data versus a magnitude subtraction due to phase errors that can result from the partial voluming [2,3]. In this study we compare complex and magnitude subtraction methods in processing arterial spin labeling data acquired using a FAIR acquisition technique.

Methods: A single-shot spin-echo EPI FAIR imaging sequence was employed in this study. Imaging was performed in 5 healthy volunteers using FAIR inversion times of 600 - 1800 ms. Other imaging parameters were FOV 24cm, slice thickness 8mm, 64x64 matrix, TE/TR=20/2000, flip angle 90°, 8-channel phased array head coil, and 40 consecutive imaging pairs were acquired over approx. 3 minutes. Data was reconstructed offline by reconstructing complex images for each coil element for each inversion state (selective and non-selective) and for each time point separately. The images from pairs of inversion states were then subtracted on a coil-by-coil basis using either a magnitude or complex subtraction. The subtracted data from all 8 coils and all 40 time points were then summed together and an image of the magnitude of the final summation was generated. A K-means clustering algorithm on a T1-weighted image was used to define all pixels corresponding to gray and white matter. SNR was calculated as the mean signal in these clusters divided by the standard deviation of the signal values in these clusters. The SNR values were compared across different FAIR inversion times and different subjects. Statistical analysis was performed using a 2 tailed students t-test.

Results: Complex subtraction shows an increase in SNR in all subjects at all inversion times compared to magnitude subtraction ($p<0.01$). Sample images from different subjects comparing magnitude and complex subtraction for all different inversion times are shown in figure 1. Figure 2 plots the SNR as a function of subtraction method vs TI time. There is a trend towards higher SNR improvements at longer TI times.

Discussion/Conclusion: Complex subtraction was shown to increase SNR of FAIR perfusion images. The increase is greater for longer inversion times. This is likely due to the increased distribution of blood throughout tissue for the longer inversion times, resulting in a greater overall partial volume effect which is compensated for by the complex subtraction. At shorter inversion times the blood has not had time to reach pixels in the image that do not contain relatively large vessels and the partial volume effects are reduced. Overall a significant increase in perfusion signal SNR can be achieved by using complex subtraction in FAIR imaging.

References: [1] Kim S.G. et al. MRM, 1995, 34:293-301; [2] Y. Wang, et al., MRM, 1996, 36:551; [3] Y. Huang, et al., JMRI, 2002, 15:541

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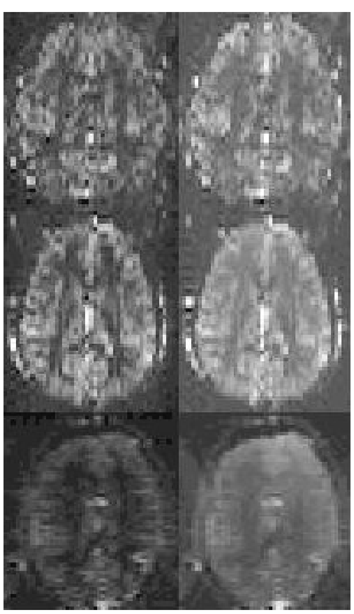

Figure 1: Comparison of magnitude subtraction (left column) to complex subtraction (right column) in different subjects with a FAIR TI=600ms (top row), TI=1200ms (middle row) and TI=1800ms (bottom row).

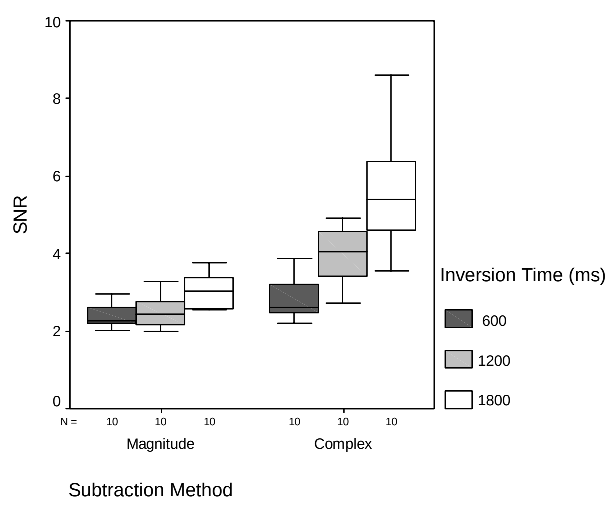

Figure 2: SNR over the entire brain for all subjects (error bars are one standard deviation) for all 3 inversion times. Complex subtraction improves SNR in all cases, however there is a greater improvement with increasing inversion times.