Fat suppression and Off-resonance Corrections for Single and Multi-echo PC VIPR

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Introduction

Radial *k*-space trajectories have been shown to allow for significant accelerations in image acquisition, especially in cases where the imaging volume is sufficiently sparse. However, objects that are off resonance either from chemical shift or B0 inhomogeneities are blurred by a radius proportional to the linear phase developed across a full projection. In the case of phase contrast (PC) VIPR, the shortening of the readout length, is limited by SNR and data acquisition efficiency [1]. This makes the sequence particularly sensitive to off resonance blurring, especially at 3T. We propose methods to measure 3D field maps without increasing scan time, which may also suppress motion artifacts from fat. The field maps can then be used to reduce off-resonance blurring in anatomical and flow images.

Methods

PC VIPR sequences were modified to allow for the creation of off-resonance field maps. For single echo sequences, projections were interweaved with shifted TE's [2,3]. Instead of extending the TR and hence the overall imaging time, the fractional echo location was switched every other projection (Figure 1). Altering the echo time causes destructive interference of low spatial frequency fat signal, which reduces artifacts caused by moving fat, such as abdominal fat moving due to respiration. Dual echo PC VIPR sequences inherently have projection sets acquired at two separate TE's which allow for the creation of off-resonance maps. For both sequences, low resolution field map estimates were created by taking the phase difference between low resolution images reconstructed from each TE. High resolution Images were then reconstructed using both echo times at multiple offset frequencies [4]. The final image was interpolated from the multiple frequency image volumes based on the field map. A normal volunteer was examined at 3.0T with PC-VIPR, with and without the proposed off-resonance correction using a 384^3 matrix, 22x22x18 cm FOV, VENC of 60 cm/s, and receiver bandwidth of 16 kHz. The images from these two acquisitions were compared to determine the efficacy of the off-resonance correction.

Results

Off-resonance maps consistently show B0 homogeneities at the base of the skull (Figure 2b). In PC-VIPR, this produces susceptibility artifacts which manifest as blurring of the arteries near the skull base in the circle of Willis, as seen in Figure 2c.. In our initial experience, the internal carotid artery (petrous, cavernous, and supraclinoid), middle cerebral arteries, and anterior cerebral arteries are most severely affected by this blurring. In our volunteer study, the use of a multi-frequency reconstruction demonstrated improved visualization of the intracranial vessels near the skull base. (Figure 2) Phantoms studies, using the single echo sequence, show a high level of fat suppression when echo times create phase shifts for fat between the short and long TE's (Figure 3).

Conclusions

We show methods for correcting off resonance effects in reliable and effective manor. Work is currently underway in exploring the effects of corrections in other areas of off-resonance including the renal vasculature in close proximity to the intestinal tract and in the pulmonary vessels.

References

1. Gu et Al. AJNR. 26:743-749;
2. Flask et Al. MRM 50:1095-99
3. Nayak et Al. MRM 43:151-154

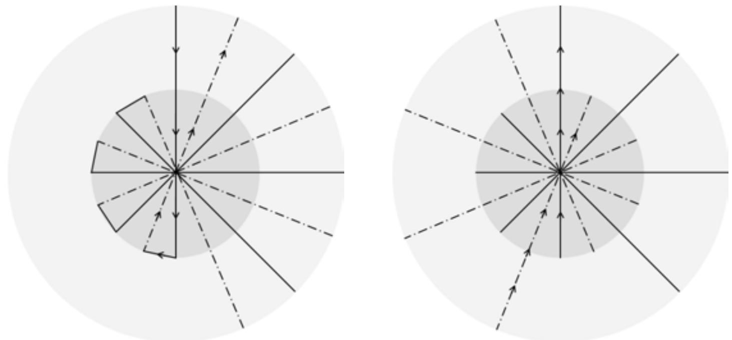

Figure 1. 2D Representations of single (right) and multi (left) echo PC VIPR trajectories. Dashed Lines represent short TE sequences while solid line represent long (TE's)

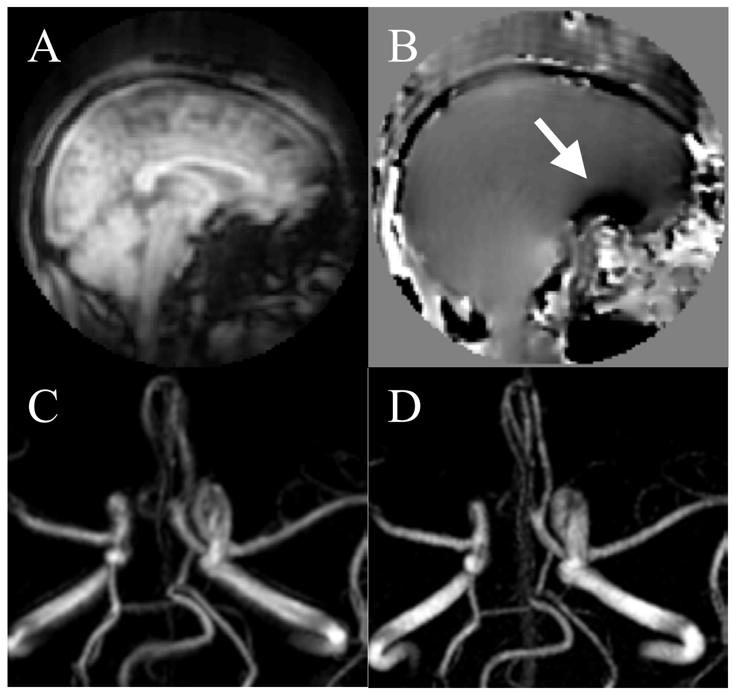

Figure 2. Low resolution magnitude (A) and off resonance(B), which are used to correct the complex difference image(C) yielding an unblurred image(D)

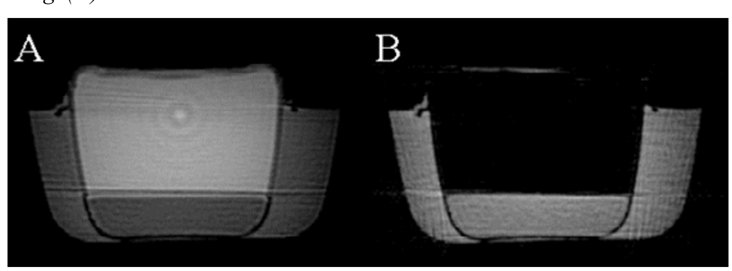

Figure 3. Low frequency fat-suppression properties of the single echo sequence. Image A is a basic sequence while B is a fat suppressed alternating TE sequence.