THE REMOVAL OF BLOOD CONTRIBUTIONS IN PHASE AND SUSCEPTIBILITY CONTRAST IMAGING

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Introduction

Recent studies suggest that phase contrast and susceptibility imaging can characterize local variations of tissue magnetic susceptibilities [1] and may have the potential to reveal local tissue microstructure in the human brain. However, despite the abundance of potential clinical applications (visualizing the cerebral venous network, quantifying endogenous iron/myelin concentrations in gray and white matter, imaging hemorrhages in stroke patients, measuring the hematocrit, characterizing tumors and other pathological conditions and tracking fibers in white matter) [4], a quantitative assessment of the tissue susceptibility requires disentangling the various underlying sources that contribute to the overall phase contrast. To this end we investigate the feasibility of reducing/removing contributions from the (paramagnetic) blood pool to the measured phase by suppressing the blood signal with diffusion weighting [2-3].

Methods

Typically, high-resolution phase contrast and susceptibility imaging are achieved using a gradient echo sequence with a sufficiently long echo time. In our implementation, a 3D SPGR sequence was modified to incorporate the flow compensated diffusion weighting packet, which was readily accommodated within the same echo time to maintain the same imaging time. To accurately compare and assess the effects with and without diffusion weighting, diffusion weighted and non-diffusion weighted acquisitions were interleaved within the same pulse sequence in alternating excitations. The use of gradient spoiling ensures that the application of diffusion gradients in alternating excitations does not alter the steady-state. As a result, the reconstructed images are perfectly registered and differ predominantly in that the contribution of intravascular blood signal. Healthy subjects were scanned on a GE 750 3-Tesla MRI scanner with the following parameters: TE/TR = 42/80ms, b=35 s/mm^2 (with flow compensation), resolution 1x1x1.5mm^3. Larger b factors can also be used to further remove the intravascular signal, however we chose this relatively small diffusion weighting in our initial implementation to keep the baseline saturation at a negligible level and to illustrate the effect. Optimization of b factor is underway for the most effective and exclusive suppression of blood signal.

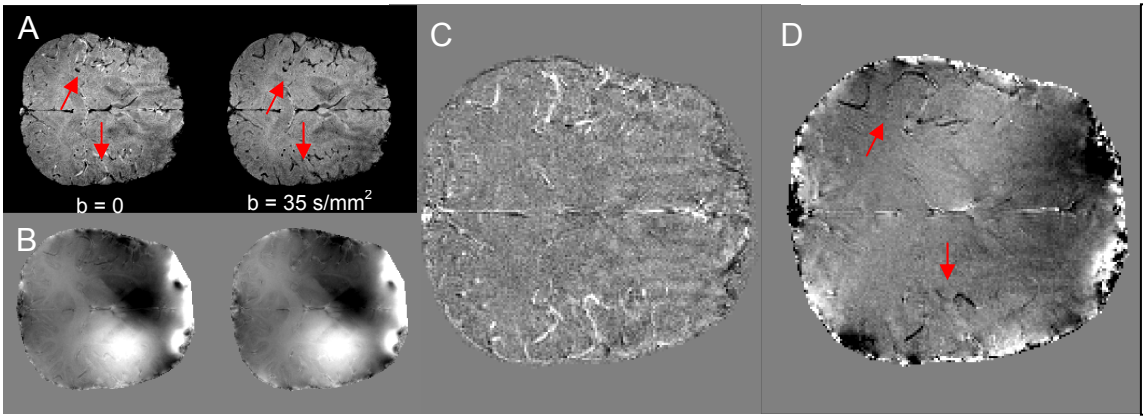

Figure 1: Magnitude (A) and phase (B) images acquired with b=0 (left) and b=35 s/mm^2 (right) respectively. Difference images (nonDW-DW) of magnitude (C) and phase images (D) shows the contribution of intravascular signal. Signal in blood vessels can alter the local tissue susceptibility.

Results and Discussion

Shown in Fig. 1 are preliminary results illustrating the effect of diffusion weighting on phase contrast and susceptibility imaging. Specially, magnitude and phase images are shown in Figs. 1A and 1B, respectively. It is evident that the intravascular signals are removed by diffusion weighting (b=35 s/mm^2). This effect is further demonstrated in the difference images in magnitude (Fig. 1C) and phase (Fig. 1D). In particular, negative phases due to intravascular effects as shown in Fig. 1D confirm the paramagnetic origin of these spins. While these effects are visually more apparent in local areas where there are large vessels (e.g. veins), they do also exist in other regions where there are smaller vessels, albeit are less evident and manifest as global signal changes weighted by the vascular density.

It should be noted that while the intravascular signals are externally removed by the use of diffusion weighting, the extravascular susceptibility effects are intrinsically cancelled as the result of within voxel averaging. As a result, the application of diffusion weighting does provide an effective means to remove blood contributions from the overall phase contrast and susceptibility images.

Conclusions

We conclude that, with the addition of simple diffusion weighting, it is possible to suppress the contribution of blood susceptibility to the measured phase and susceptibility differences. This separation is critical to allow more exclusive evaluation of tissue contrast without vascular contaminations. We believe that this is an important step toward a quantitative measurement of the susceptibility contrast in vivo, and may lead to improved assessment of specific tissue microstructure (e.g. myelin) that gives rise to the susceptibility contrast.

References: 1. Duyn et al., PNAS 2007;28:11796, **2**. Song et al., MRM 1996;35:115, **3**. Turner et al. Radiology 1990;177:407, **4**. Haacke et al., AJNR 2009;30:19