Multishot Diffusion Weighted FSE with PROPELLER

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Introduction
Multiple-shot FSE methods for diffusion-weighted MRI (DWI) have far less susceptibility-related artifacts (from metal, sinuses, and eddy currents), and have less intensive gradients requirements than those of single-shot EPI DWI. Despite this promise, multi-shot FSE DWI faces two major challenges. First, the extremely high phase-sensitivity to motion requires some sort of navigator information to remove this phase prior to combination of data over multiple diffusion weightings(1,2,3,4). An alternative to this is the use of radial sampling(5). Second, the signal will not in general meet the CPMG condition, leading to an unstable echoes. Alsop introduced a method to solve the CPMG problem, but at a 50% loss in signal (6). Other solutions to the CPMG problem have recently been proposed by LeRoux (7,8,9). The proposed work is based on the PROPELLER method (10), which has inherent 2-D navigator information in each FSE echo train, and builds on much of this previous work.

Method Description
Diffusion weighted PROPELLER FSE methods collect data along a series of strips, or blades, in k-space as illustrated in Fig. 1.

Since each blade goes through the center of k-space, the phase error introduced by motion during the diffusion gradient application can be removed prior to the combination of blades, provided the phase is spatially slowly varying. The phase correction method is similar to that discussed in (10). Many other methods use navigator information to translate the k-space origin, which only corrects for rigid-body motion; this phase correction is much more robust.

The problem of non-CPMG artifacts was mitigated by alternating the phase of the refocussing pulse within the echo train, e.g. {180x-180y-180x-180y-...}, with appropriate changes in the reconstruction to account for differences between odd and even echoes. This method, based in part on work by LeRoux (7-9), is described in more detail in another abstract at this meeting by Pipe.

Implementation and Results
PROPELLER diffusion-weighted FSE was implemented on a GE 1.5T NV/i scanner. All diffusion weighted images shown here have a b value of 1000 sec/mm², a slice thickness of 5mm, a FOV of 24cm, an effective matrix of 256, and 1 NEX. Figure 2 shows a patient who was symptomatic after aneurysm clipping. The signal warping from the clip makes it hard to diagnose in the EPI image, while the PROPELLER image shows a clear diffusion abnormality. The image in Fig. 2 had a TE of 150 msec, and required separate reconstruction from odd and even echoes. Recent improvements to this method (see other abstract by Pipe) have resulted in reduction of the TE to 100msec, and allowed image formation from all echoes simultaneously. This resulted in faster imaging time, better SNR, and less artifacts. Examples of images in a normal volunteer are seen in Fig. 3.

Discussion
The proposed method has greatly reduced sensitivity to magnetic field inhomogeneities compared to EPI methods. It is also much more feasible to acquire high-resolution DWI than with single shot EPI imaging. There is a 50% increase in imaging time over conventional FSE due to the oversampling in the center of k-space. This same oversampling also mitigates residual motion artifacts, and aids SNR.

References