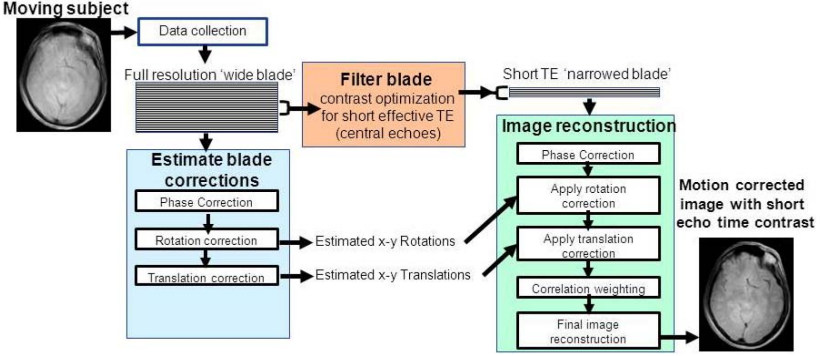
Fast Spin Echo T1w and PDw PROPELLER with Motion Correction using Extended Echo Trains

James H Holmes[1], Philip J Beatty[2,3], Howard A Rowley[4], Ann Shimakawa[5], and Jean H Brittain[1,6]

[1]Global Applied Science Laboratory, GE Healthcare, Madison, WI, United States, [2]Global Applied Science Laboratory, GE Healthcare, Toronto, ON, Canada, [3]Physical Sciences, Sunnybrook Research Institute, Toronto, ON, Canada, [4]Radiology, University of Wisconsin-Madison, Madison, WI, United States, [5]Global Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States, [6]Canada

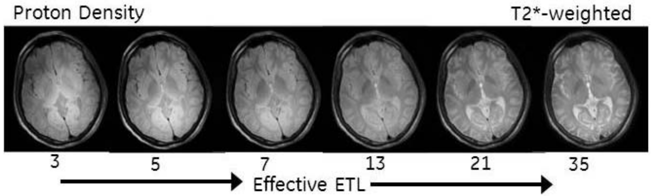
Introduction: T1-weighted (T1w) and proton density (PDw) weighted fast spin echo (FSE) acquisitions are routinely used in the clinical setting with typical echo train lengths of ~4 to provide sufficient image contrast and reasonable scan times as compared to Spin Echo. The PROPELLER acquisition method has been demonstrated to provide excellent motion correction capabilities for T2-weighted multi-slice imaging [1]. However standard PROPELLER motion correction methods rely on relatively wide imaging blades, requiring long echo trains that result in compromised image contrast for short echo time applications. A PROPELLER based FSE acquisition for T1w and PDw weighted imaging with motion correction would be highly desirable for the clinical setting. Here we describe a novel method to enable robust motion correction while maintaining the desired T1w or PDw contrast. The method acquires wide PROPELLER blades and applies motion correction parameters derived from the full blade width while reconstructing only the center centrically-acquired optimal-contrast lines for the image reconstruction.

Figure 1. Motion correction algorithm (blue box) estimates correction parameters from wide full resolution propeller blades. Blade data is then filtered (orange box) to create a narrow blade with optimal contrast. The final image is then reconstructed (green box) using the optimal contrast narrow blades with motion correction parameters from full resolution data



Methods: Eleven volunteers were imaged on standard clinical 3 T MRI system (Discovery MR750, GE Healthcare Waukesha, WI) using an 8 channel brain coil (MRI Devices, Waukesha, WI). PROPELLER acquisition parameters included centric phase encoding with echo train lengths (ETL) of 29-35. TE = 8.3 ms, TR = 3 s or 792 ms for PDw and T1w respectively, FOV ~24 cm × 24 cm, 320 readout, 5 mm slice and BW ±50 kHz. The TR time for the extended ETL T1w acquisition was adjusted to normalize the time for recovery following the readout train to match that of a standard 4 ETL acquisition with TR = 550 ms. For stationary volunteers, 60 PROPELLER blades were acquired while 140 blades were acquired during volunteer motion to allow sufficient angular sampling in the event that some blades were excluded due to out of plane motion [1]. A flow chart of the motion correction algorithm is shown in Figure 1. Conventional PROPELLER motion correction algorithms were used to estimate corrections for rotation and translation based on the full acquired blade width (Fig. 1 blue box). Next, each blade was filtered in the phase-encode direction to limit the contribution of later echoes, effectively narrowing the blade width (Fig. 1 orange box). For T1w and PDw comparisons, an effective width of 5 encodes was used. The narrow blades were then combined to form a PROPELLER image using the motion correction parameters determined from the full resolution blades (Fig 1, green box). Normal volunteers were imaged while stationary and during voluntary head motion. For comparison, conventional Cartesian FSE images were acquired with an ETL of 4 and TR of 3 s for PDw and 550 ms for T1w.

Figure 2. Same acquired data reconstructed using varying blade widths from a centric encoded acquisition. Note ability to transition from PDw to T2w contrast within the same data set as the effective TE is increased due to inclusion of later FSE echoes (exterior of the Propeller blade).



Results: By varying the effective ETL of the PROPELLER blades used for final image reconstruction, the contrast can be seen to vary from T2w to PDw with no compromise in motion correction capability (Fig. 2). Examples of PDw imaging with a Cartesian acquisition and the proposed PROPELLER method are shown in Fig. 3. Comparable contrast is shown when the volunteer was stationary but significant improvement is found with the new PROPELLER method with volunteer motion. Results for T1w imaging are shown in Fig. 4 demonstrating comparable image contrast using the PROPELLER method with the capability to recover image quality in the event of subject motion.

Figure 3. Comparison of proton density weighted images from the Cartesian and proposed PROPELLER method. Note comparable contrast in stationary images and significant improvement in image quality when the subject is moving while maintaining high PDw contrast.

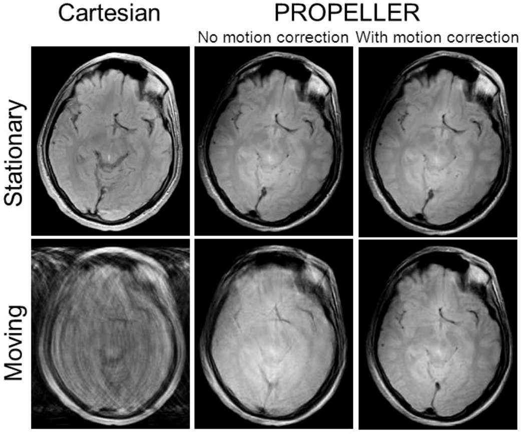
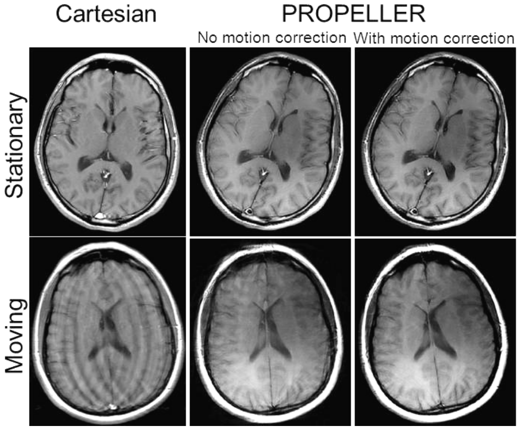


Figure 4. Comparison of T1w Cartesian and the proposed PROPELLER method. Note comparable contrast when the subject is stationary. The proposed motion correction method allows image recovery with T1w contrast during significant head motion.



Conclusions: We have demonstrated a novel method for generating motion-corrected PROPELLER images with short echo-time high T1w/PDw contrast by using centric encoding with extended ETLs to provide inherently co-registered high resolution blade data for motion correction and narrow PROPELLER blades for optimal image contrast. One advantage of our technique is that there is no dependence on parallel imaging to achieve the desired image contrast making it more practical for the single-channel coils often used for MSK applications. However the method can readily be combined with parallel imaging for greater reductions in scan time and T2 blurring. The method may also be readily combined with alternative PROPELLER acquisition strategies [2,3] and algorithms used for estimating motion parameters [2].

References: [1] Pipe et al. MRM 1999;42:963-969. [2] Pipe et al. MRM 2006;55:380-385 [3] Skare et al. MRM 2006:55:1298-1307.[4] Tamhane et al. MRM 2009;62:174-182