External Calibration Parallel Imaging for Improved Motion Correction Capabilities with T1 FLAIR PROPELLER

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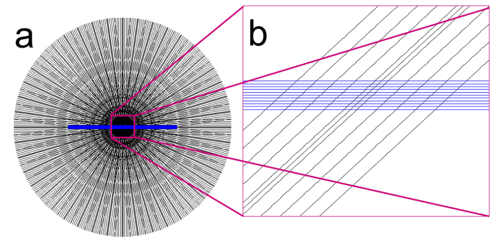
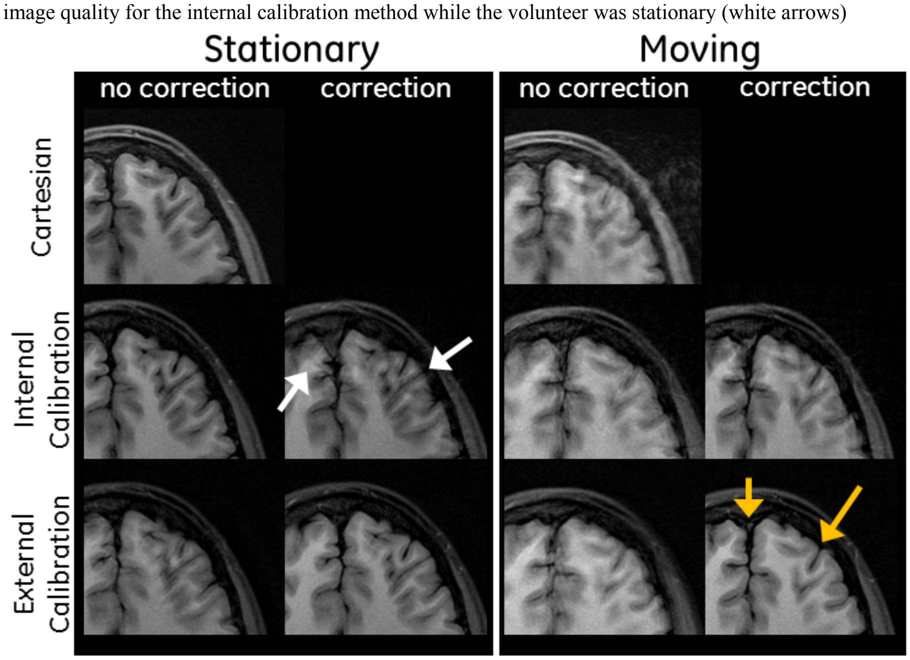
Introduction: T1 weighted imaging with motion correction presents several challenges. The PROPELLER method has been shown previously to provide excellent motion correction, however the motion correction requires wide blades [1]. With current methods, it is not possible to achieve sufficient blade width for motion correction while also maintaining the short echo train length needed for optimal T1 contrast. Parallel imaging provides an opportunity to increase the effective blade width. Autocalibrating parallel imaging (API) methods provide greater robustness to motion compared to methods that require explicit information about coil sensitivity. However conventional API methods require calibration that must be repeatedly acquired and applied on a blade by blade basis. We present a method to share a single acquired calibration data set with all imaging blades on a slice by slice basis using the APPEAR non-Cartesian parallel imaging method [2,3]. This allows an effective blade width increased to 27 enabling robust motion correction. Results comparing a conventional API PROPELLER method to the proposed technique are shown in normal and clinical volunteers demonstrating robust motion correction in moving subjects without loss of image quality in subjects that are stationary.

Figure 1. a) Acquisition trajectory with an over-sampled calibration blade (blue) and accelerated blades (black). b) Enlargement of the calibration blade and a single accelerated blade.



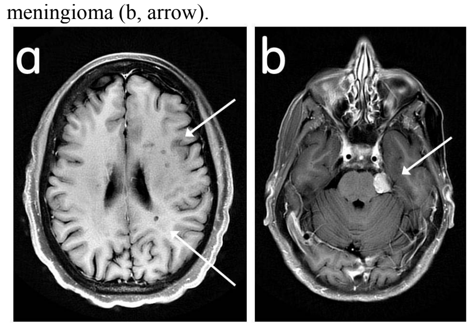
Methods: Seven normal volunteers were imaged using externally calibrated PROPELLER, conventional internally calibrated PROPELLER, and Cartesian acquisitions. Each acquisition was performed twice, once while the volunteers were stationary and once during intentional head movement. Seven clinical volunteers were also imaged following their routine clinical exams that included contrast injection. Imaging was performed on standard clinical 3 T MRI systems (MR750 and Signa HDx, GE Healthcare Waukesha, WI) using an 8 channel brain coil (MRI Devices, Waukesha, WI). Acquisition parameters included echo train length (ETL) of 11, TE = 43.5 ms, TR = 3 s, FOV ~24 cm × 24 cm, 384 readout, 28 x 5 mm interleaved slices in 2 acquisitions and BW ±50 kHz. Inversion times ranged from 920 ms to 1.2 s to assess robustness to different image contrasts. Total scan time was 5 min and 45 blades were acquired to maintain sufficient angular sampling following possible rejection of some blades due to extreme head motion. Figure 1 shows the k-space readout lines for the proposed technique. A single calibration blade (blue lines) is acquired with oversampling by 2× in the frequency and 1.5× in the phase encoding directions. Accelerated blades (black lines) are undersampled by 3× in the phase encoding direction with only 2 fully sampled lines at the center. With linear view ordering, the 11 echo per blade acquisition provides high T_1 contrast, while the effective reconstructed blade width of 27 still enables effective motion correction [4]. Calibration coefficients were calculated using data interpolated from the calibration blade onto the undersampled imaging blade using the APPEAR algorithm. An internally calibrated PROPELLER acquisition was performed using the same acquisition parameters but 4 internal calibration lines were acquired and used to reconstruct each blade to an effective width of 13; 47 blades were acquired to maintain full angular sampling. Cartesian images were acquired with 384 readout, 0.9 phase FOV, 320 phase encodes, and matching slice coverage and inversion time.

Figure 2. Magnified views of the frontal lobe from images of a volunteer at rest and during motion. Note the images from the external calibration technique reconstructed with motion correction resulted in significant improvements in image quality during motion (orange arrows) without loss of quality when the volunteer was stationary. Due to insufficient blade width, the motion correction resulted in degraded image quality for the internal calibration method while the volunteer was stationary (white arrows)



Results: In all data from the comparison studies, the external calibration PROPELLER was found to maintain image quality in stationary subjects when motion correction was applied and it allowed significant improvements when the subjects were moving. However, the motion correction with internal calibration PROPELLER method was found to degrade image quality for stationary subjects due to insufficient blade width. Both PROPELLER techniques were found to reduce pulsatility artifacts found in the stationary Cartesian images and provided improved image quality during volunteer motion. Example images are shown for one of the volunteers during the stationary and moving studies (Fig 2). An example image from a clinical volunteer with multiple sclerosis depicts small non-enhancing plaques (Fig. 3a, arrows) and an enhancing tentorial meningioma is well visualized in a second clinical volunteer (Fig. 3b, arrow).

Figure 3. 32 year old female with chronic non-enhancing multiple sclerosis plaques (a, arrows). 45 year old female with an enhancing left tentorial meningioma (b, arrow).



Conclusions: The use of externally calibrated PROPELLER has been shown to provide robust motion correction capabilities despite short ETLs needed to maintain good T1 FLAIR contrast. This was demonstrated in normal volunteers in whom no sacrifice in image quality was made when subjects were stationary and significant improvements in motion correction were visible when the subjects moved during the acquisition. This work is of particular interest in non-cooperative patients including studies of dementia and pediatrics.

References: [1] Pipe et al. MRM 1999;42:963-969. [2] Beatty et al. ISMRM 2008 A1464. [3] Beatty et al..ISMRM 2007 A335. [4] Chang et al. ISMRM 2008 A3115.