Parallel Imaging PROPELLER with Across-Blade Calibration: *In Vivo* Results

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Parallel imaging PROPELLER with across-blade calibration [1] is a data-driven parallel imaging approach that combines internal (intra-blade) calibration with calibration from an external "calibration blade". APPEAR non-Cartesian parallel imaging [2] enables an external calibration blade to be used across all blades, regardless of rotation angle. Simulations have shown that this approach is able to achieve high net acceleration factors while being resilient to motion [1].

In this study, the *in vivo* performance of parallel imaging PROPELLER with across-blade calibration is evaluated by collecting multiple accelerated PROPELLER axial brain scans during subject motion. Reconstruction results indicate that the combined calibration approach is able to more consistently remove aliasing artifacts, compared to either internal or external calibration alone. In addition, in some cases the improved aliasing artifact removal of the combined calibration approach materially improved motion correction.

Theory Data-driven parallel imaging generates unaliasing coefficients by fitting data at 'source' locations to 'target' locations over multiple training examples. Because all training examples do not need to have the same subject position or contrast, it is possible to generate unaliasing coefficients from training examples taken both from within an accelerated blade and from a calibration blade, even when the subject has moved between blade acquisitions [1].

Methods Two volunteers were scanned on a 1.5T scanner (Signa® HDx, GE Healthcare, Waukesha, WI) using an 8-channel brain array and a PROPELLER trajectory with six accelerated blades, illustrated in Fig. 1a. Each accelerated blade used an acceleration factor of three, with two additional calibration phase-encodes. In addition, a separate calibration blade was acquired within the scan (Fig. 1b); the calibration blade was over-sampled for a 1.5X field-of-view (as recommended for APPEAR non-Cartesian calibration [2]). This blade was used to aid in generating the unaliasing coefficients, but did not contribute to the final image. All acquisitions were in the axial plane and used an FSE sequence with an echo-train-length (ETL) of 24: the effective width of each accelerated blade was 64 lines (net per blade acceleration factor of 64/24 = 2.67). The calibration blade had an effective width of 24/1.5=16 lines. The TE for all scans was 100 ms while the TR values ranged from 800-2000 ms. The subjects were asked to move during the scan. To reconstruct each image, unaliasing coefficients were applied to fill in the missing data on each accelerated blade; these fully sampled blades were then passed to a standard PROPELLER reconstruction [3] for motion correction and combination. Unaliasing coefficients were generated in three different ways: 1) using only the internal calibration data; 2) using only the external calibration blade; and 3) combining internal and external calibration. Images were reconstructed for each data set and each set of unaliasing coefficients.

Results and Discussion Representative results are shown in Fig. 2. In all cases, reconstruction using only internal calibration resulted in visible aliasing artifacts (Fig. 2a,d,g); this is not surprising due to the paucity of internal calibration data. While increasing the number of internal calibration phase encodes would likely produce better results, this would reduce the net acceleration factor and shrink the blade width, making motion correction more challenging. Data set #1 shows a case where the visible aliasing artifacts were removed with only external calibration (Fig. 2b). However, external calibration alone was not sufficient to remove the aliasing artifacts from data set #2 or #3 (Fig. 2e,h). Figure 2h shows an example where the residual aliasing artifacts have affected the PROPELLER motion correction method: note how (h) is rotated relative to (i). Figure 2c,f,i show reconstruction results for combined internal/external calibration. For all three data sets, the combined calibration approach was better able to remove aliasing artifacts and the PROPELLER reconstruction was better able to correct for the subject motion.

Since PROPELLER is typically used to reduce motion-related artifacts, it is important that any parallel imaging that is combined with PROPELLER also be resilient to motion artifacts. This study demonstrates that parallel imaging PROPELLER with across-blade calibration performs well in the context of motion. In addition to using parallel imaging to reduce the acquisition time of PROPELLER imaging, opportunities also exist to 1) improve motion correction through the use of wider blades and 2) use shorter echo trains to reduce blurring due to T2 decay or geometric distortions in the case of diffusion tensor imaging.

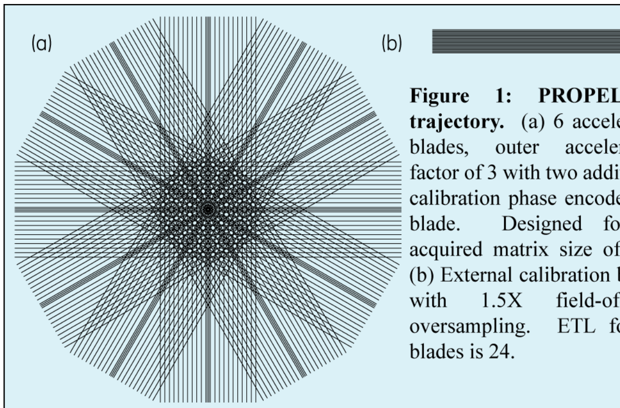

Figure 1: PROPELLER trajectory. (a) 6 accelerated blades, outer acceleration factor of 3 with two additional calibration phase encodes per blade. Designed for an acquired matrix size of 256. (b) External calibration blade, with 1.5X field-of-view oversampling. ETL for all blades is 24.

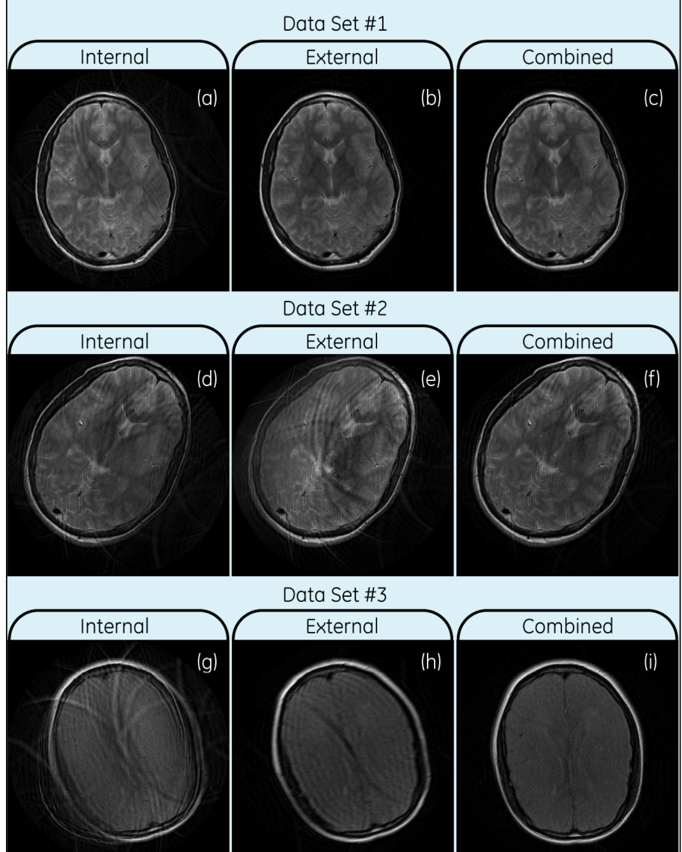

Figure 2: Reconstruction results for *in vivo* data sets with motion.
Unaliasing coefficients were generated using:
Left column Only the internal calibration data.
Middle column Only the external calibration blade data.
Right column Combined internal calibration data and external calibration blade data.
The combined approach is better able to remove aliasing artifacts in the presence of motion.

References

[1] Beatty and Brau, ISMRM Workshop on Non-Cartesian MRI 2007, p44.
[2] Beatty et al. ISMRM 2007, p335.
[3] Pipe, MRM 42:963-9, 1999.