Turbo PROPELLER with Asymmetric Blade

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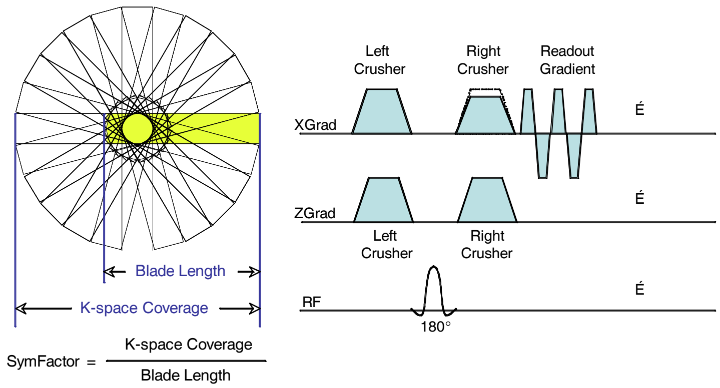
Introduction: PROPELLER [1] FSE imaging has been shown to be very effective for T2 imaging. Turbo-PROP [2] was proposed to provide T1-weighted MR imaging. In Turbo-PROP, small EPI readout trains are used in an FSE sequence to acquire multiple k-space lines in a single echo. We propose using an asymmetric blade, which includes the center area of k-space, but only one half of the remaining outer area. This small blade is then rotated 360 degrees to cover all of k-space. This goal is to shorten each echo, thus reducing echo-train length and susceptibility artifacts.

Methods and Results: The regular Turbo-PROP sequence was modified on a GE 3.0T SIGNA scanner to collect the data with asymmetric blades and 360° rotations (Figure 1a). The offset from the k-space center was achieved by adjusting the areas of the left and right crushers in the frequency direction, as shown in Figure 1b. Collected data were put into the correct position in k-space based on their offsets, and regular PROPELLER reconstruction was applied. We defined “SymFactor” (symmetry factor) as the ratio of k-space diameter to blade length, as shown in Figure 1a. Simulations were performed with noise-only data at different SymFactors, assuming same acquisition time but different resolution. Reconstructed noise-only images were synthesized and the standard deviations of noise were measured (Blue column in Figure 2). As expected, the noise standard deviation is roughly proportional to the square of the SymFactor (e.g. the effective pixel size). After normalized by the square of the SymFactor (pixel scaling), the difference in noise (Red column of Figure 2) is primarily determined by the different weights used in gridding. Phantom study was carried with a GE quadrature head coil and standard resolution phantom. Images were acquired with same “Blade Length” and different SymFactors, and one could observe the tradeoff between SNR and resolution (Figure 3). The noise standard deviations in the phantom images were measured and they agreed very well with the simulation results (Not shown here). Human brain images were acquired from a healthy volunteer with same “K-space Coverage” and different SymFactors. The number of blades was adjusted to keep the scan time the same. With asymmetric blade acquisition, the susceptibility artifacts were reduced, as shown in Figure 4.



(a) (b)

Figure 1. The 360° rotation of asymmetric blades are shown in (a), and the offset from the k-space center is achieved by adjusting the area of crushers in XGrad, as shown in (b)

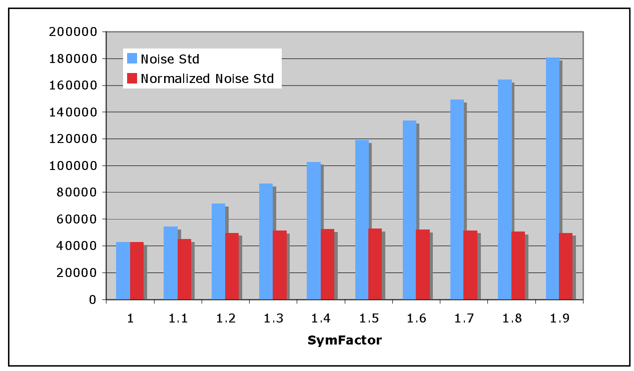


Figure 2. The noise standard deviations change with the SymFactor (Blue). The noise standard deviations normalized by the effective pixel size are shown with the red columns.

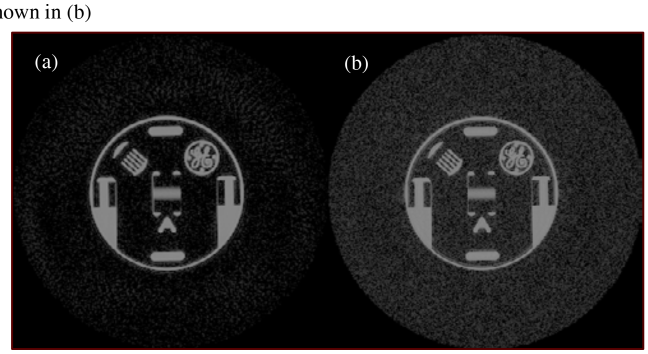


Figure 3. Phantom images acquired with same acquisition time and blade lengths but different SymFactors. (a) SymFactor = 1 and (b) SymFactor = 1.5.

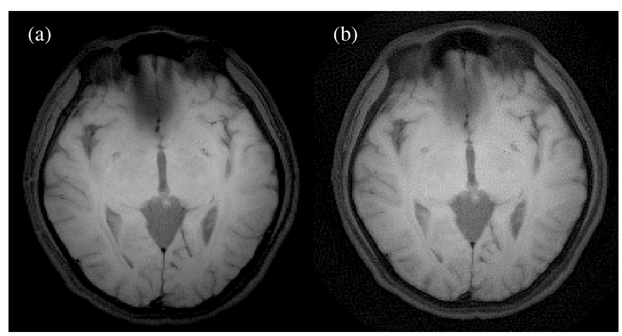


Figure 4. Axial brain images acquired with same acquisition time and resolution but different SymFactors. (a) SymFactor = 1 and (b) SymFactor = 1.5.

Discussion: The use of asymmetric blades provided an opportunity to further accelerate the data acquisition of Turbo-PROP. More importantly, the T1 contrast was enhanced and the susceptibility artifacts were reduced.

References: [1] Pipe. MRM (42), 5, 963-969, 1999. [2] Pipe. MRM (55), 2, 380-385, 2006.

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