3D FFE PROPELLER Free-Breathing Abdominal Imaging

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PURPOSE: A common goal for abdominal MRI is the collection of free-breathing data with minimal respiratory artifacts. To reconstruct accurate images, maximize patient comfort, and enhance temporal resolution, we propose a PROPELLER [1,2] based 3D FFE sequence and reconstruction method for free-breathing data acquisition in dynamic abdominal studies. For this proof-of-concept study, in which there was no dynamic process (e.g. no Gad injection), performance was judged based on the consistency of temporally resolved images over ~4 minute scan in two healthy volunteers.

METHODS: The proposed PROPELLER based method acquires 3D blades from an excited slab that contain N_Z (kz) x N_Y (ky) phase encoding lines. The kz lines are collected one line per TR in the "inner loop" of data collection, and the ky phase encodings are encoding in a center-out fashion (Fig. 2). A new blade is started after a trigger from respiratory bellows (set for end-exhalation) by (1) resetting the ky phase encoding to 0, and (2) rotating the blade angle by the golden angle. At the trigger, the current kz loop is completed before starting the next blade. Hence, each blade encodes the center ky lines during end-exhalation, and has a width $N_Y = \left\lceil \frac{T_{span}}{TR \times N_{kz}} \right\rceil$, where T_{span} represents the time span between two adjacent respiratory triggering as shown in Fig. 1(a), and $\lceil . \rceil$ rounds a number up to the next larger integer. The k-space data are stored consecutively, as shown in Fig. 1(b), with ky lines stored in temporal order.

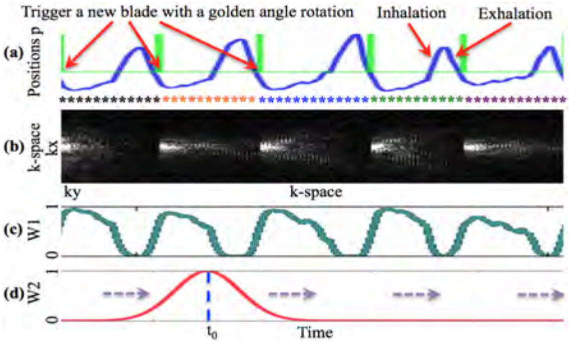

Fig. 1 shows an example of the signal acquired from the respiratory bellow during respiratory triggering (vertical light green bar in (a)) and acquired ky profiles (star points with different colors in (b)). Blade width is dynamically determined by the time span between two adjacent respiratory triggering. Weighting functions w1 (c) and w2 (d) apply on SDC weights for all blades.

As in conventional PROPELLER, data weighting is used to preferentially reject undesired data. This is achieved by assigning relative weights to ky lines based on their "goodness"; these relative weights are used in calculating sampling density weights, which in turn preferentially use the preferred data in the gridding process. A weighting function $W1 = e^{-p^2/\sigma_1^2}$ was assigned to every ky line, where p is the position of the respiratory bellow (normalized between 0 and 1). As shown in Fig. 1(c), the lines corresponding to end-exhalation - generally the middle of each blade - will be weighted more than outer ky lines. A second, temporal weighting function $W2 = e^{-(t-t_0)^2/\sigma_2^2}$ was also assigned to each ky phase encoding direction. As shown in Fig. 1(d), t_0 can be shifted over a predefined time interval to produce multiple temporal-weighted images for observing dynamic abdominal imaging. Temporally weighted reconstruction using (A) only W2, and (B) the product of W1 and W2, was performed on the same data sets, with the expectation that the latter would reduce artifacts from the inclusion of end-inhalation data. Two healthy volunteers with naturally breathing were scanned using the proposed PROPELLER sequence with 3D T1-weighted FFE on a Philips Ingenia 3T MR scanner. For each scan, 16 6-mm thick slices were acquired with an in-plane FOV and resolution of 40 cm and 2x2mm^2, flip angle 5°, and TE/TR = 2.0ms/4.5ms. All images were reconstructed by GPI [3] using $\sigma_1 = 0.3$ and $\sigma_2 = 30$.

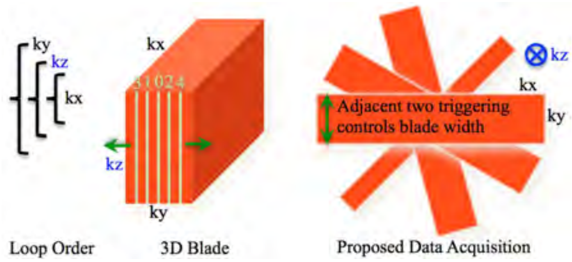

Fig. 2 shows nested loop order, one blade slab, and acquisition patterns (with 4 blades). The double-headed arrow (green) indicates that when a new blade is triggered, central blade data is acquired at first and then outer lines on blade acquired.

RESULTS AND CONCLUSION: The results in Fig. 3 show that 3D PROPELLER images with weighting (B) can reduce respiration artifacts (pointed by red) and improve image sharpness (pointed by green) in compared to images with weighting (A). The overall quality of three temporal images is improved by adding W1 to the reconstruction as shown in Fig. 3. Experimental results demonstrate that the proposed method is able to reduce respiration artifacts and sharpen images. Future study will make use gadolinium for abdominal DCE-MRI and assess temporal resolution.

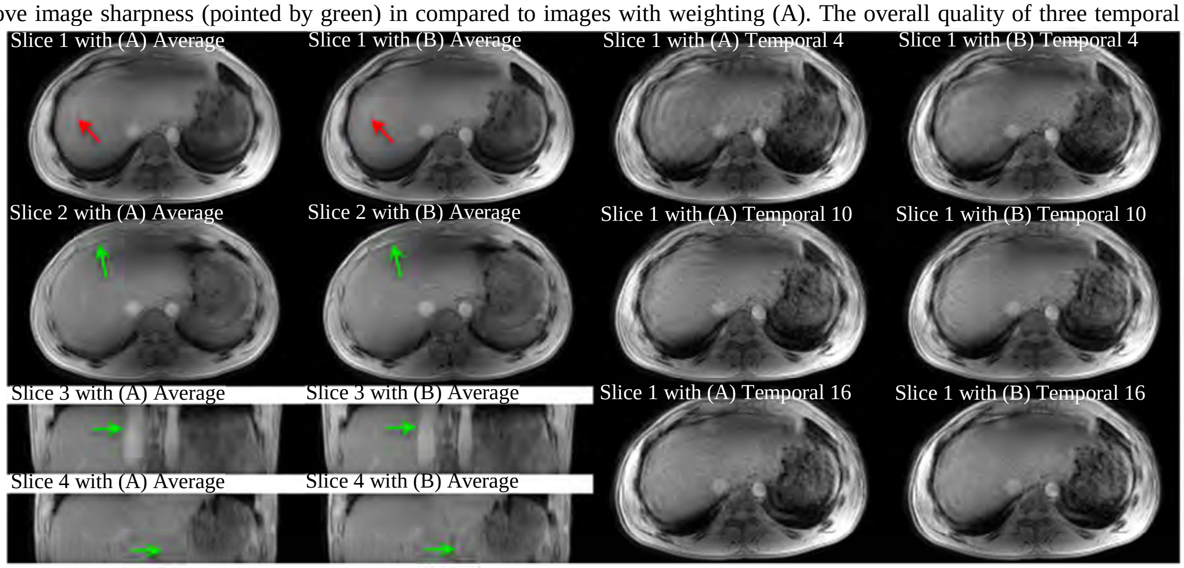

Fig. 3. Performance comparison between weighting schemes (A) and (B) for the average of all temporal images on each of 4 slices (left two columns), and 3 temporal images of the slice 1 (right two columns).

REFERENCES: [1] Pipe J, MRM 42:963 [2] Pipe J, et al, MRM 72:430. [3] Zwart N, et al, MRM DOI 10.1002/mrm.25528, 2014.

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