Variable Pitch PROPELLER: Motion Corrected MultiSlab 3D MRI

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Introduction: PROPELLER MRI allows one to collect motion-corrected T2 and diffusion weighted images using a fast spin echo (FSE) approach[1,2]. Although these applications have proven clinical utility, the restriction to 2D methods is limiting. In previous work, quadratic encoding has been developed as a novel hybrid between 2D and 3D methods[3,4]. In this work, quadratic imaging is added to a 2D PROPELLER sequence (together called Variable Pitch PROPELLER), allowing one to have the SNR benefits of a "multi-slab" 3D sequence along with the motion correction inherent in conventional PROPELLER (using the standard reconstruction algorithms already developed).

Quadratic Encoding Summary (more details found in refs. [3,4]): Quadratic encoding uses a constant-magnitude rf pulse with a linear frequency sweep ("variable pitch", bandwidth M/τ) over the duration τ of the rf pulse; in the presence of a gradient G_z, this excites a slab with a resulting parabolic phase profile in the slice direction (Fig. 1b vs. Fig 1a). The data are collected as a stack of overlapping 2D slices with center-to-center spacing $1/(\gamma G_z \tau)$ and thickness $M/(\gamma G_z \tau)$. After the slices are collected, one can Fourier transform them in the slice direction, remove a quadratic phase in k_z, then inverse transform them back into a stack of slices with true resolution of $1/(\gamma G_z \tau)$.

Variable Pitch PROPELLER: A 2D gradient echo pulse sequence was altered by adding a quadratic encoding rf pulse, and collecting the data in the following order: (inner loop) collect N lines per blade in N TR's, then collect the same blade for all slices (middle loop), and then (outer loop) rotate the blade, until all blades for all slices cover k-space. In this manner, the median rotation and shift position for each slice (which the PROPELLER algorithms attain) should line up those slices fairly well prior to quadratic "deblurring" through the slices. (Fig. 1c).

Method: Variable Pitch PROPELLER was implemented on a GE 1.5T EXCITE echo-speed plus scanner. Images of a volunteer (Fig. 1(d-f)) illustrate the SNR benefits of quadratic encoding (Fig. 1f vs. 1d) and the comparable resolution of the image regardless of collected slab width (collected 1.5mm thick slabs in Fig 1d, 18mm thick in Fig. 1(e,f)).

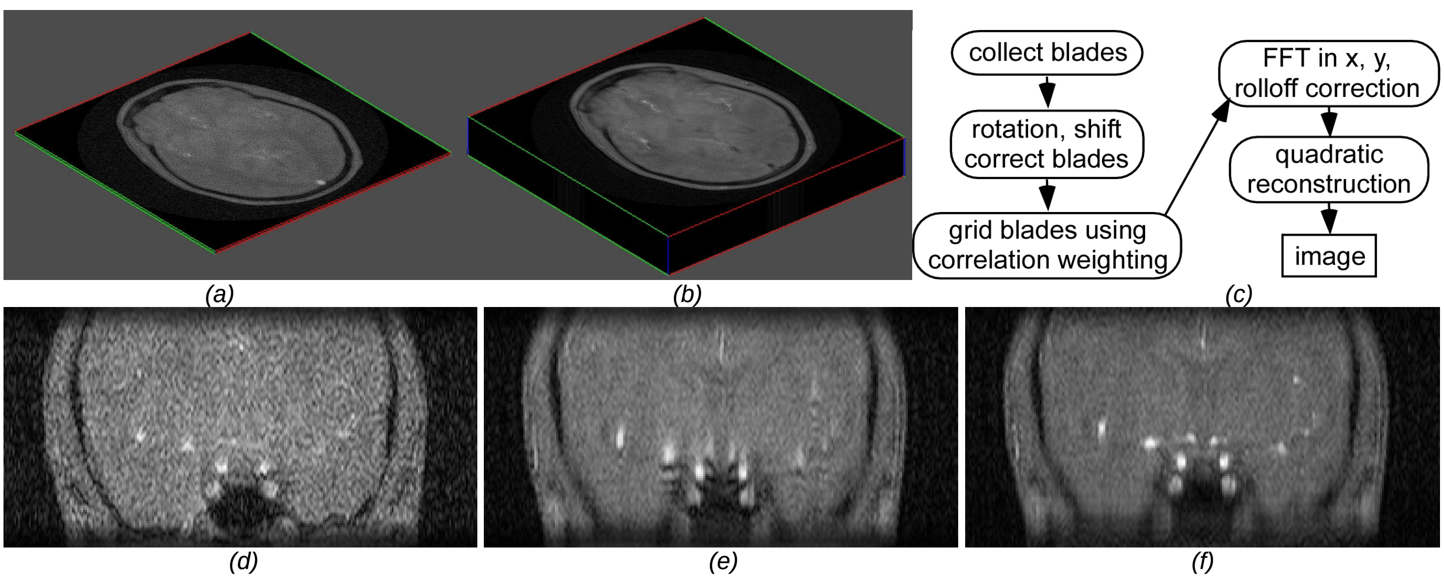

Fig. 1. Illustration of (a) 2D slice and (b) quadratic-encoded slab, and (c) flow chart for reconstruction. Coronal reformations of VP-PROP data (collected as axial slabs) for (d) M=0 (i.e. standard 2D), (e) M=12, as collected, and (f) M=12, after deblurring.

Discussion. The addition of quadratic encoding to a gradient echo sequence with PROPELLER data acquisition creates a multi-slab 3D sequence that can employ standard PROPELLER motion correction. We are currently investigating clinical use of this method for motion-corrected MOTSA TOF-MRA, in which the slab moves contiguously, and T1 weighted imaging, in which the slab order is alternated to maximize T1 contrast-to-noise.

References: 1. Mag Res Med 42(5), 963. 2. Mag Res Med 47(1), 42. 3. Mag Res Med 36(1), 137. 4. Mag Res Med 39(4), 625.

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