Parallel Imaging for Sliding Interleaved Cylinder (SLINCY) Acquisition

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Purpose: A sliding interleaved cylinder (SLINCY) acquisition [1] is a variation of a sliding interleaved k_y (SLINKY) [2] acquisition in which a 3D concentric cylinders trajectory [3] is used as the readout instead of a 3DFT sequence. Due to the helical sampling geometry of the readout trajectory and the sliding-nature of the acquisition scheme, a dedicated parallel imaging strategy is required for SLINCY to achieve a clinically feasible scan time. In this work, we developed a new parallel imaging strategy for SLINCY that decomposes the 3D helical structure of SLINCY into a series of 2D Cartesian planes to reconstruct each slice independently.

Methods: SLINCY: The SLINCY acquisition consists of a series of overlapped thin slabs for volumetric coverage, with the increment of slab location equal to the resolution in the slab direction (Fig. 1a). For each thin slab, one of N interleaved subsets of cylinders (Fig. 1a) is collected. Still, each slab is fully sampled in k_z, so slices can be reconstructed without aliasing in the z direction. Previously [1], each slice was reconstructed by combining partial data from N corresponding slabs after 3D gridding.

Parallel Imaging for SLINCY: The sampling geometry of cylinders for each slab is designed in a way that the entire 3D helical data can be reformatted as a set of 2D Cartesian spoke-planes [4], where all the sampling points are aligned in the k_z direction (Fig. 1b). With this geometry, slices are reconstructed in a hybrid space (z-k_x-k_y) after a 1D inverse fast Fourier transform (IFFT) and a subsequent linear phase correction to compensate the shift in the k_z direction (Fig. 1b). Partial data of each slice from N corresponding slabs are then combined, where the k-space data still remain on the original locations of sampling points in k_x and k_y. Now, each slice can be reconstructed independently, with 2D gridding when fully sampled (Fig. 2a), or with any non-Cartesian parallel imaging method when undersampled (Fig. 2b). SPIRiT [5] reconstruction is used in this study for the latter case. Undersampling is achieved by skipping slabs, e.g., skipping every other slab for a reduction factor of R = 2. For autocalibration, few innermost cylinders are acquired additionally, which slightly decreases the effective R.

Imaging Parameters: In vivo studies of the lower extremities on healthy volunteers were performed on a GE Excite 1.5 T scanner with an 8-channel receiver-coil array. Gradients for the SSFP version of the SLINCY acquisition were designed to provide isotropic resolution = 1.2 mm and FOV = 340×340×38.4 mm^3 for each slab. TE/TR = 3.6/7.2 ms, and flip angle = 60°. For a fully sampled scan A, 256 slabs with N = 16 were acquired in two stations to cover 25 cm in the S/I direction. For an undersampled scan B, only 128 slabs with increment between slabs 2.4 mm instead of 1.2 mm were acquired with the first 16 cylinders fully sampled for autocalibration. Total scan time was 8 min 10 s and 4 min 20 s for scans A and B, respectively.

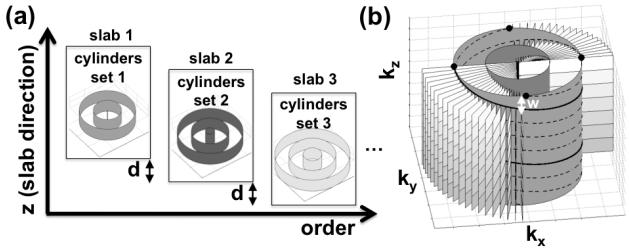

Fig. 1. (a) Data acquisition scheme of SLINCY. A partial set of cylinders is collected at each slab in an interleaved way, incremented by a distance d equal to the resolution in z between slabs. **(b)** A 3D concentric cylinders k-space trajectory with four helical readouts shown on the outermost cylinder. Depicted are 20 of a total of 40 full-diameter spoke-planes, which are slightly shifted ($\boldsymbol{w}$) in the k_z direction due to the helical readouts.

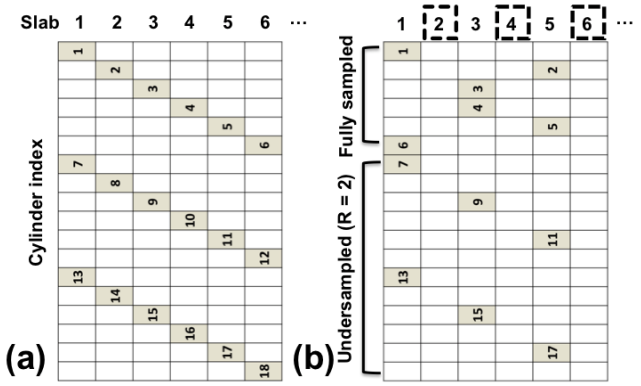

Fig. 2. Acquisition scheme of SLINCY (N = 6) with 18 cylinders. **(a)** Fully sampled. **(b)** Undersampled (R = 2) with the first six cylinders fully sampled for autocalibration. For (b), slabs within dashed rectangles are not acquired, which originally collected cylinders with even indexes.

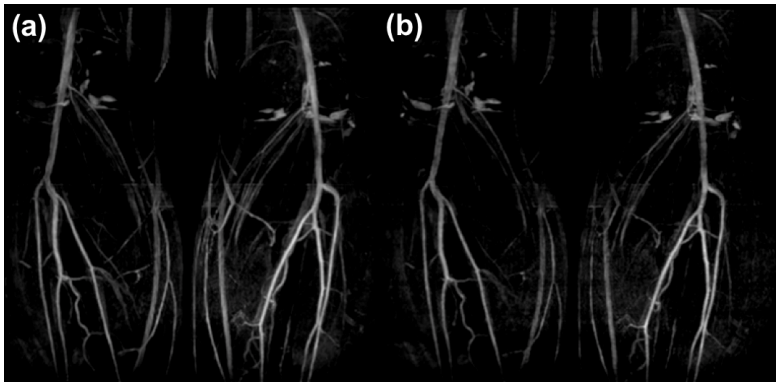

Fig. 3. Targeted coronal MIP (factor of two zero-padding) of the lower extremities with SLINCY. **(a)** Fully sampled. **(b)** Prospectively undersampled (R = 2).

Results: Figure 3 shows targeted coronal MIP images of the lower extremities from (a) the fully sampled dataset and (b) the prospectively undersampled dataset. The undersampled dataset reconstructed with the proposed parallel imaging strategy shows comparable image quality to the fully sampled case other than the decrease in SNR.

Discussion/Conclusion: In this work, we demonstrated that the proposed parallel imaging strategy is feasible for SLINCY, which reduced the scan time down to almost 50% with the R = 2 undersampling. The key feature of the proposed strategy is the use of 1D IFFT to isolate the reconstruction of each slice from others, which was enabled by the tailored sampling geometry of the cylinders. Otherwise, the entire 3D cylinder dataset needs to be considered together, which would require 3D gridding/inverse-gridding pairs and may not be as efficient as the proposed strategy.

References: [1] Kwon et al., 20th ISMRM, p.3898, 2012. [2] Liu et al., JMRI 1998;8:903. [3] Ruppert et al., 11th ISMRM, p.208, 2003.

[4] Kwon et al., 19th ISMRM, p.2887, 2011. [5] Lustig et al., MRM 2010;64:457.