Whole-Body 3D Continuously Moving Table Imaging using Radial and Spiral Sampling

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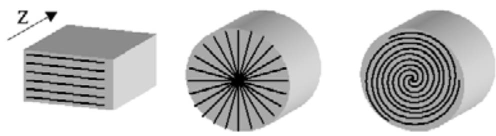
Introduction

Continuously moving table imaging is of growing interest in a number of applications [1,2], allowing efficient acquisition of 3D data from an unrestricted virtual FOV. So far, Cartesian sampling schemes [1-4] have typically been employed for that purpose. However, non-Cartesian schemes are conceivable as well, offering a number of interesting features such as reduced motion sensitivity or robustness against *k*-space sub-sampling. Thus, 3D radial imaging [5] has been proposed recently for peripheral angiography. In this work, alternative 3D schemes, namely, the 3D radial (stack-of-stars) and 3D spiral (stack-of-spirals) schemes were studied to examine their potential for continuously moving table imaging.

Methods

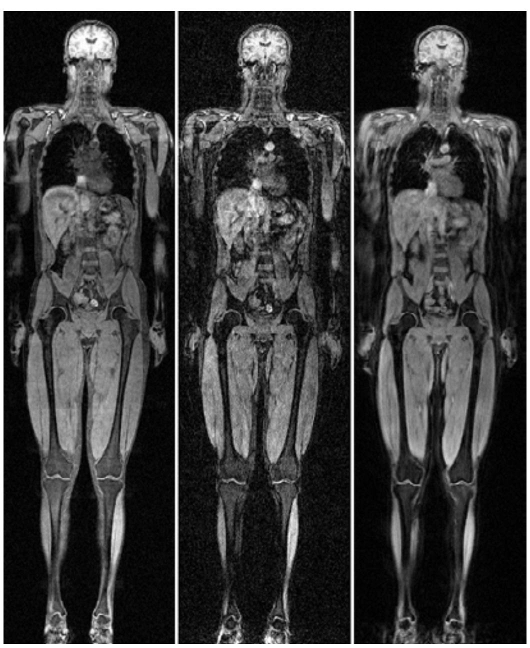
In-vivo experiments were performed on healthy volunteers, using a 1.5 T whole-body scanner (Achieva, Philips Medical Systems). The body coil was used for RF transmission and signal reception. The patient table was moved at constant velocity during data acquisition. To show the feasibility of the 3D stack-of-stars and stack-of-spirals methods for continuously moving table acquisition, the lateral frequency encoding approach proposed for Cartesian sampling [4] was chosen and modified. (Other implementations are conceivable as well.) In the present approach, a 3D gradient-echo sequence is applied with the phase encoding along the direction of motion, *z*, whereas the transverse plane is covered either by radial or by interleaved spiral sampling (c.f. Fig.1). The phase encoding in *z*-direction is performed in the inner-most scan loop, such that the full set of phase encoding steps is applied for each radial readout or spiral interleave. The position of the RF-excitation slab is moved synchronously with the velocity of the patient during one cycle of phase encodings. The *k*-space data are corrected for the table motion using phase modulation [2] and shift in hybrid space k_x,k_y,z [1]. Final reconstruction is performed via 2D gridding [6] and Fourier transformation.



type	TE/TR	AQ	d/shots	profiles	T
Cartesian	1.7/4.4	2.0	2/16	48x60	5:09
Radial	1.9/4.9	2.0	2/16	48x60	5:24
Spiral	1.4/13.8	10.0	1/6	16x60	4:50

Fig. 1. Sampling schemes and parameters

A virtual FOV of 512 × 1970 × 256 mm³ corresponding to a voxel size of 2.67 × 2.67 × 5.33 mm³ was reconstructed, using an elementary FOV_z of 123 mm in motion direction. Measurements using full Cartesian sampling were performed for comparison. The spiral and radial imaging schemes were performed with sampling of isotropic voxels (length 2.67 mm), followed by appropriate summation after reconstruction to obtain the 5.33 mm coronal slice thickness. Fat suppression, using magnetization preparation, was necessary to compensate for the off-resonance sensitivity (here the fat) of the spiral scan, but was applied in all scans for comparability. The corresponding sequence parameters are given in Fig.1. *AQ* given in [ms] denotes the signal sampling time per profile (readout or interleaf), *T* the total measuring time in minutes and *d/shots* the number of dummies/measured profiles in the segmented acquisition after fat suppression. To reduce the scan time, radial sampling was performed with the angular sampling density reduced to 25%, whereas Cartesian sampling was performed in a rectangular FOV of 25% aspect ratio. The table velocity was adjusted for each of these protocols to satisfy the matching condition for the contiguous elementary FOVs (v = 6.1, 6.8, and 6.4 mm/s for the radial, spiral and Cartesian schemes, respectively). To cope with the body-susceptibility induced f_0 shifts, appropriate demodulation was performed prior to spiral reconstruction to reduce blurring.



(a) **(b)** **(c)**

Fig. 2. Selected slices from 3D data sets for the Cartesian (a), stack-of-radials (b) and stack-of-spirals (c) sampling schemes.

Results and Discussion

Figure 1 shows one slice from 3D data for each of the examined sampling schemes and one selected volunteer. For comparison, a Cartesian result is included. No moving-table imaging artifacts are visible although no correction was applied for system imperfections. However, the streaking artifacts in the radial case, which result from sub-sampling, limit the performance of the radial approach with the parameters used. These artifacts can be reduced either by non-uniform angular sampling [7], adapted to the elliptic transversal body cross-section, or by parallel imaging. Spiral imaging showed the best SNR, due to the longest total signal sampling time (1.56-fold of the radial or Cartesian). The fold-over artifacts visible near the shoulders could be reduced by choice of a larger FOV or by use of variable-density spiral sampling. The off-resonance sensitivity of the spiral requires the application of fat suppression. Also, position-depended signal demodulation is necessary, complicating the reconstruction.

Conclusion

The stack-of-spirals and stack-of-radials sampling schemes were shown to be applicable in continuously moving table imaging, but their general applicability seems to be limited. However, after further improvements and optimization of parameters, they can potentially find a place in selected high-contrast applications as e.g. peripheral angiography.

References

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