Free-breathing, self-navigated RUFIS lung imaging with motion compensated image reconstruction

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Target audience – MR and PET scientists and clinicians interested in motion correction and lung imaging.

Purpose – Lung imaging is challenging due to short signal lifetime and low proton density. Ultra-short- and zero-TE sequences such as RUFIS[1] are particularly adapted for this application. In this context, high resolution 3D imaging is highly desirable but requires motion management. Gibiino et al[2] have proposed prospective gating solutions. However the scan time remains long due to the low scan efficiency. Here, we propose a new sampling pattern associated with a motion compensated reconstruction to take advantage of the whole scan time.

Methods – ***Subjects:*** 2 healthy volunteers ***Acquisition:*** At 3T (MR750w, GE Healthcare, WI) 4 datasets were acquired with the RUFIS sequence: in free breathing and in breath-hold (BH), with 1.1mm and 1.6mm isotropic resolution. The trajectory was modified such that each segment 1) covers homogeneously the k-space periphery with a spiral, 2) is negligible (276ms for 1.6mm, 368ms for 1.1mm) against the breathing dynamic, and 3) starts with a z navigator. The segments were interleaved with a golden angle rotation around the z-axis (Fig.1) such that the reconstruction of an image with any arbitrary selection of segments always corresponds to a quasi-homogeneous sampling of the k-space periphery. The scan parameters were: TE=0, BW=±62.5kHz, 256 spokes per segments, scan time: 1min45s (1.6mm) and 3min10s (1.1mm) in free-breathing (acceleration factor at the periphery R=2π), 26s in BH (R=8π). ***Reconstruction:*** The volumes were reconstructed with a non-Cartesian iterative self-calibrated SENSE reconstruction[3] constrained with TGV regularization[4,5]. Four volumes were reconstructed out of the free-breathing dataset: 1) using 100% of the data (FB), 2) Retrospective Gating using 50% of the data the closest to the end-expiration (RG), 3) by Reconstructing 8 gates, non-rigidly Registering[6] and Averaging them (RRA) and 4) by integrating the motion extracted from the gates into a Motion Compensated Reconstruction (MCR)[7]. The 3 latest reconstructions used the self-navigator to select or bin the data (Fig.2) ***Data analysis:*** The signal obtained with the self-navigator was compared to the reference obtained with a breathing belt simultaneously recorded. The reconstruction methods were compared using measures of the vessel and liver sharpness, the apparent SNR, the darkness of the bronchial tubes and the reconstruction time factors.

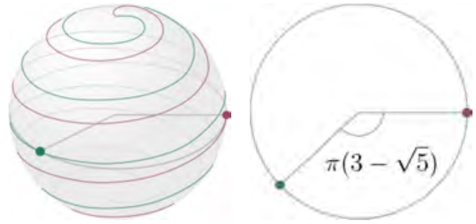

Fig.1 The tip of the spokes describes a spiral for each segment. Two interleaved segments are separated by a rotation of the golden angle around the z-axis

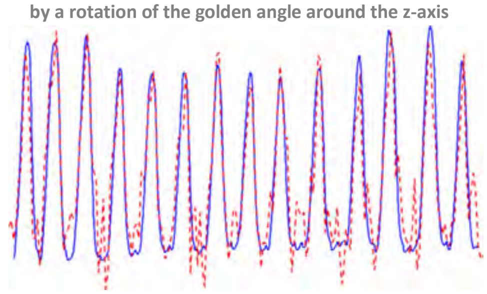

Fig.2 Belt signal (blue, solid) vs. self-navigator (red, dotted)

Results – The correlation between the self-navigator and the belt was r^2 = 77%. One sagittal maximum intensity projection of the 5 reconstructed volumes are presented in Fig.3. In the following, the measures are presented from worst to best, sharpness (mm): FB(5.5)<BH(2.6)<RG(2.5)<RRA(2.2)<MCR(1.9), SNR: BH(6.6)<RG(9.3)<RRA(13.7)<FB(14.4)<MCR(15.4), darkness (% of soft tissue signal): BH(27.6)<FB(26.5)<RG(14.6)<RRA(13.7)<MCR(11.6), computation time factors: MCR(15)<RRA(9)<FB(4)<RG(1.5)<BH(1).

Discussion – The new trajectory gives the advantage of ensuring a homogeneous sampling for RG. As expected, MCR gives better image quality than RRA at the cost of computation time[8]. TGV regularization is of great value but its parameters must be carefully selected for such an inhomogeneous structure like the lungs. The reconstructed volume well depicts the lung density variation, which could be exploited for attenuation calibration in the context of PETMR.
Conclusion – The proposed method presents potential benefits for PET/MR since it provides high-resolution anatomical imaging, renders the lung density, and extracts a custom motion model with a free-breathing acquisition.

References – 1. Madio et al. MRM 1995, 2. Gibiino et al. MAGMA 2014, 3. Pruessmann et al. MRM 2005, 4. Bredies et al. SIIMS 2010, 5. Knoll et al. MRM 2011, 6. Menini et al. ESMRMB 2013, 7. Batchelor et al. MRM 2005, 8. Cruz et al. ISMRM 2014
Acknowledgment – V.G. is supported by a grant from Deutsche Telekom Foundation

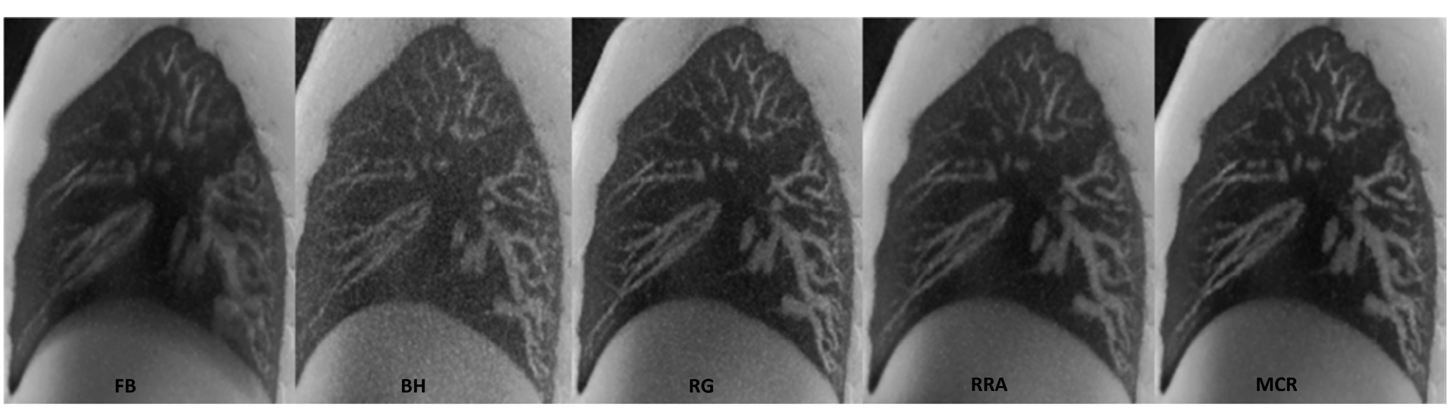

Fig.3 Sagittal maximum intensity projection (18mm slab) of the 5 reconstructed volumes (1.1mm isotropic resolution). From left to right: Free Breathing dataset without motion correction (FB), Breath-Hold (BH), Retrospective Gating (RG), Reconstruct-Register-Average (RRA), and Motion-Compensated Reconstruction (MCR)