Respiratory self-gating using 3D half-echo stack-of-stars TrueFISP (TrueSTAR)

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Target audience. Physicists and physicians interested in lung imaging methods.

Purpose. Breath-holding is the simplest method used in pulmonary MRI to avoid ghosting artifacts and blurring caused by the respiratory motion but may pose a problem for patients with compromised respiratory function, uncooperative patients or children. Here, besides common navigator techniques or respiratory bellows[1,2], a self-gating technique previously proposed in combination with gradient echo and ultra short echo time pulse sequences[3,4] can be used to track respiratory phases. Generally, breathing motion causes a signal modulation in the *k*-space center and consequently radial *k*-space sampling is particularly useful for tracking signal modulations with high temporal resolution. Here, for the first time, an ultra-fast 3D hybrid radial stack-of-stars half-echo balanced steady-state free precession (bSSFP) sequence with golden-angle increments[5] was used for retrospective respiratory self-gating pulmonary MRI at 1.5T.

Methods. All data were acquired on 1.5T MR scanner (MAGNETOM Avanto, Siemens Healthcare, Erlangen, Germany) with a 12-channel chest array and a 24-channel spine coil. Three healthy volunteers were scanned in supine position using a 3D hybrid radial stack-of-stars ultra-fast bSSFP sequence with the golden-angle projection reordering and half-echo readout. Free breathing scans were completed within 7 min and were performed with and without fat saturation (FS) using 6000 and 5200 half-echo radial projections, respectively. A slice thickness of 6 mm (40 slice encodings) and 400^2 mm^2 FOV were used for a reconstruction matrix of $128^2 \times 80$, resulting in an in plane-resolution of 3.1 mm^2. Other sequence parameters were: TE/TR = 0.85/1.21 ms, $\alpha = 15°$, bandwidth = 1700 Hz/px. Radial data was reconstructed using a gridding algorithm with a Kaiser-Bessel kernel.

Time delays in encoding gradient usually cause deviations from ideal *k*-space trajectories resulting in off-center image artifacts. Corrections of the *k*-space trajectory were accomplished by the modification of the imaging gradient moments with the following gradient delays characteristics: -3.2 us for x-axis and -1.8 us for z-axis. For a coil element located in the diaphragm region, signal time-courses from the *k*-space center were postprocessed in the frequency domain using a low-pass Fermi filter to eliminate angular dependent signal modulation. Subsequently the filtered signal time-course was used for data binning in order to generate images in different phases of the breathing cycle.

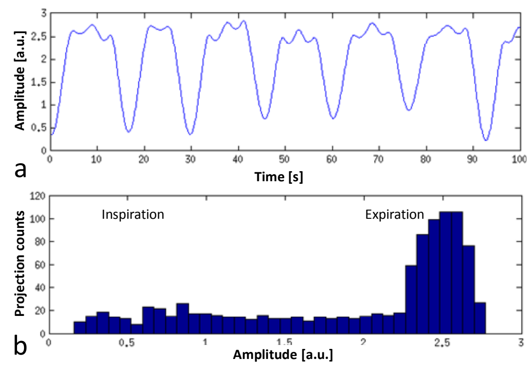

Figure 1. *Time-course plot (a) shows the modulation of signal amplitude in k-space center during free breathing in 3D stack-of-stars radial bSSFP acquisition. Histogram (b) presents the distribution of projections in different phases of the respiratory cycle.*

Results. Figure 1 shows an exemplary time-course of the filtered signal modulation in the *k*-space center with its corresponding distribution of radial projections along the respiratory cycle. Notably, most of the acquisition time was spent during expiration. *In vivo* chest images of a healthy volunteer are shown in Figure 2. The end-expiratory reconstruction without FS (in Figure 2a) is characterized by pronounced streaking artifacts resulting from high intensity signal oscillations of fatty tissue. These residual artifacts can be successfully removed using fat saturation (Fig. 2b), but coronal and sagittal composite bSSFP-FS images (Figure 2a) show blurred morphological structures especially in basal lung region and near the diaphragm if all available radial projections were used for reconstruction. Finally, Figure 2b shows bSSFP-FS images reconstructed using 25% of the data acquired in end-expiration. The delineation of small blood vessels within the lung as well as the definition of the diaphragmatic region is significantly improved following self-gating. No banding artifacts are visible in the lung and mediastinum.

Discussion and Conclusion. In this work we introduced a 3D hybrid radial stack-of-stars bSSFP with golden angle projection reordering for self-gating and half-echo readout for banding artifact removal and increased temporal resolution. The *in vivo* results corroborate the feasibility of bSSFP self-gating resulting in decreased blurring and improved delineation of pulmonary structures. Moreover, as a result of the chosen sampling scheme, cardiac pulsation artifacts are not visible or propagated along the Cartesian dimension. Future work will focus on clinical studies and further technical improvements, such as parallel imaging or iterative reconstruction for suppression of the streaking artifacts, to either improve temporal resolution for self-gating or spatial resolution. In conclusion, radial stack-of-stars bSSFP represents a promising new method for pulmonary MRI, especially for patients with impaired lung function, children or uncooperative patients with respiratory diseases.

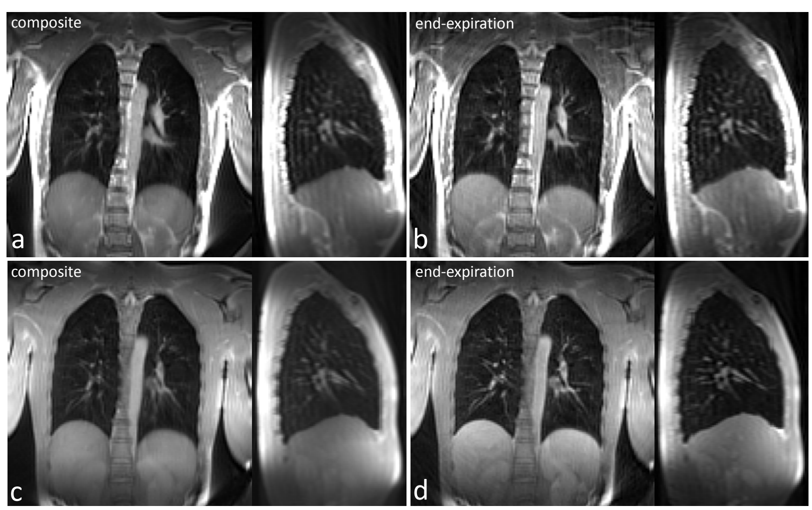

Figure 2. *Coronal and sagittal 3D hybrid radial stack-of-stars bSSFP lung images: (a) composite reconstruction using all radial projections (bSSFP); (b) reconstruction using 25% of the acquired data in the end-expiration (bSSFP); composite reconstruction (bSSFP-FS); (d) reconstruction using 25% of the data in the end-expiration (bSSFP-FS).*

References:

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