MULTI-SLICE IMAGING OF THE ABDOMEN DURING FREE BREATHING USING A RADIAL SELF-GATING TECHNIQUE

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Target Audience – Researchers working with radial trajectories and performing dynamic imaging.

Purpose – MR imaging of the abdomen is limited by breathing motion which causes blurring and ghosting artifacts in MR images. To eliminate these effects gating techniques or data acquisition during breath hold are commonly used. While the quality of breath hold imaging data is limited due to the constricted short measurement time, gating techniques provide several, more flexible opportunities to obtain motion corrected images[1]. In this work a radial self-gating method is presented for high resolution multi-slice acquisition of the abdomen during free breathing by using a radial multi-echo gradient-echo sequence and incrementing the radial rotation angle based on the Golden Ratio[2].

Methods – For multi-slice imaging of the abdomen a sequence was developed which acquires a projection navigator[3] in an additional slice, which was automatically added to the planned slice stack (Fig. 1). In this navigator slice only data for generating the respiratory trigger signal is obtained. Within one *repetition time* (TR) the sequence first collects one readout signal in the navigator slice which is always aligned in the same orientation, followed by the acquisition of readouts in each of the measurement slices that are progressively rotated by using a golden angle scheme[2]. After 1D-FFT of each navigator readout signal, a projection of the navigator slice is obtained for each TR. By performing correlation analysis between all navigator projections respiratory phases are identified and excluded from image reconstruction by a manually chosen threshold.

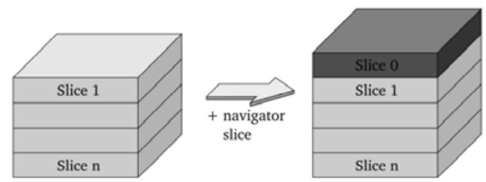

Fig. 1. In addition to the planned slices (1…n) the sequence adds a navigator slice (0) where only data for the generation of a respiratory trigger signal is acquired.

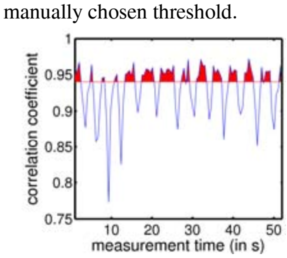

Fig. 2. The first 50 s of the generated trigger signal are shown. The threshold at a correlation coefficient from 0.94 is delineated by a red line which defines the red marked breathing phase.

The radial sequence was implemented using the *Object Oriented Development Interface for NMR* (ODIN)[4] framework. Abdominal measurements were performed on a clinical 3T System (TIM Trio, Siemens Healthcare) on a healthy volunteer (m., age 21 years) using 3 channels of a vendor supplied body array and spine coil. Measurement parameters were: acquisition matrix size 240 x 240, FOV 336 x 336 mm^2, spatial resolution 1.4 x 1.4 x 3.0 mm^3, TR = 516.57 ms, TE = 4.9 / 9.8 / 14.6 ms, FA = 50°, 377 measured radial readouts in each slice, 50 kHz acquisition bandwidth and 25 measured slices with 3 mm gap in between. To improve SNR and in order to obtain a fully sampled *k*-space after self-gating 7 repetitions were acquired, resulting in a total measurement time of 22:43 min. Image reconstruction was performed offline using MATLAB by 2D-gridding with iterative grid weights estimation[5] followed by a 2D-FFT.

Results – Resulting images during free breathing without navigator correction showed substantial blurring, particularly at the edges of the kidneys and the liver (Fig. 3a). By using the navigator data a trigger signal was generated to correct for respiration (Fig. 2). The time resolution of the trigger signal is given by the repetition time TR (here 516.57 ms). The correlation threshold was manually set to 0.94 (red line in Fig. 2). Thus, 40 % of the measured data were used for respiration corrected image reconstruction (Fig. 3b), which resulted in images with low artifact level as can be seen at the edges of the kidneys in the difference images (Fig. 3c). Furthermore, increasing the echo time provided increased T_2^* contrast (Figs. 3 and 4).

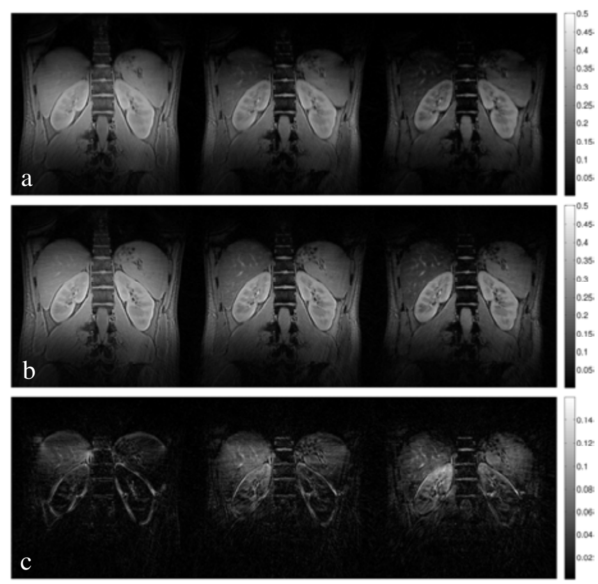

Fig. 3. Shown is a central slice of the kidney out of 25 acquired slices. The echo time increases from left to right (4.9 ms, 9.8 ms and 14.6 ms) showing increased T_2^* contrast. In (a) images are shown during free breathing whereas in (b) the breathing corrected images are depicted. The absolute differences (c) are highest at the edges of the kidneys.

Discussion & Conclusion – In this work a new method for multi-slice acquisition covering whole organs during free breathing has been proposed by using a radial self-gating technique for respiratory correction. Due to the acquisition of the navigator signal in a slice adjacent to the planned volume stack a trigger is obtained which is closely related to the measured object but does not cause saturation effects in the measurement slices. As the radial rotation scheme is based on the Golden Ratio, *k*-space is still uniformly covered after retrospective gating. The time resolution of the trigger signal corresponds to one TR and thus depends on measurement parameters and the number of acquired slices. While the breathing motion has been sufficiently sampled in the presented data set, different combinations of measurement parameters may lead to undersampling of the trigger signal. Therefore, the sequence could be extended to acquire an increased number of navigator readouts within one TR. As the used correlation threshold influences improvement of image quality and SNR of the corrected images, the threshold has then to be optimized appropriately.

References – [1] Ehman RL, et al. AJR. 1984;143(6):1175–1182. [2] Winkelmann S, et al. IEEE Trans Med Imaging. 2007;26(1):68-76. [3] Krämer M, et al. J. Magn. Reson. Imaging 2013;Epub ahead of print. [4] Jochimsen TH, et al. J Magn Reson. 2004;170(1):67-78. [5] Zwart NR, et al. Magn Reson Med. 2012;67(3):701-10.

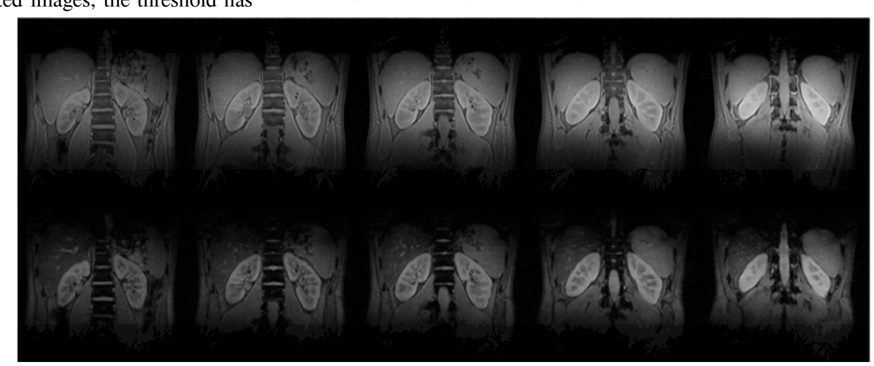

Fig. 4. Respiration corrected images of five slices (TE_1 = 4.9 ms first row, TE_3 = 14.6 ms second row).