Free breathing 3D lung imaging

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Introduction:
In pulmonary MRI, respiratory motion and blood flow cause artifacts and degrade image quality. Therefore, lung imaging is usually performed during breath-hold in the end-diastole phase, which limits the total acquisition time and the achievable SNR. Furthermore, most patients do not have the ability to hold their breath for several seconds. To overcome these limitations, additional respiratory gating/triggering devices can be used, such as respiratory belts or navigator echos [1,2]. While respiration belts have a poor gating resolution, conventional navigator echos (pencil beams) induce saturation artifacts in the lung volume.
In this work, we propose a different free-breathing navigator (NAV) echo approach, which uses the whole imaging volume (= lung volume) for navigation. This technique enables not only correction for respiratory motion, but also triggering to the heart cycle.

Methods:
All measurements were performed on a Siemens Vision Scanner (Siemens Medical Solutions, Erlangen, Germany). In a first step, only navigator echos (= non phase encoded echos) were acquired along the head/foot direction over the entire thorax (experiment A). Data acquisition was performed during free-breathing, using the following imaging parameters: flip angle 8°, resolution in head/foot direction 1.7 mm, TE = 1.8 ms, and TR= 12 ms. A 1D Fourier Transformation was performed on the resulting data, and a least squares fit to determine the diaphragm position was performed for respiratory motion analysis [3]. For analysis of the different heart phases, the signal intensities over the heart volume were summarized and plotted over time.

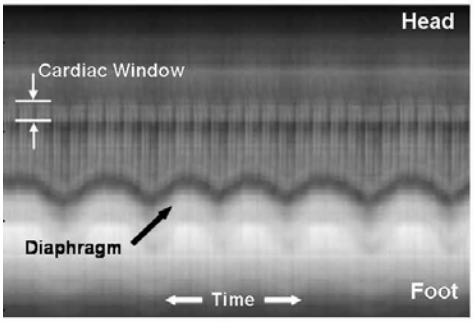

Figure 1: Time course of NAV-echos during free-breathing. Indicated are the diaphragm position and the window for calculation of the heart phase.

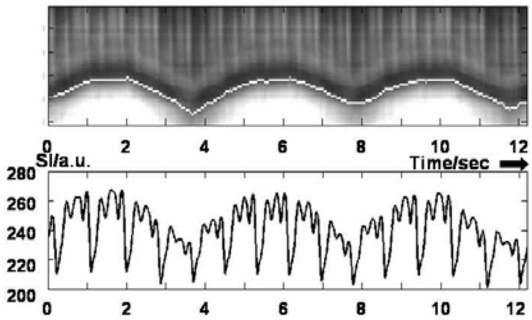

Figure 2 Top: Zoom of figure 1 showing diaphragm movement, where the white line depicts the diaphagm position. Bottom: Corresponding phases of the heart cycle. The signal drop depicts the heart beat.

The proposed navigator technique was implemented in a retro-gated 3D-gradient echo sequence (experiment B). So far, only respiratory gating has been performed, due to memory restrictions of the scanner. Therefore, an external ECG triggering device was used, and imaging was only performed in the end-diastole phase. Imaging paramters: TE= 2.7 ms, TR= 830 ms, flip angle= 8°, Matrix size 254x256 x 24 (Read/Phase/Partitions) at a resolution of 1.7 x 1.7 x 4.0 mm^3.The total acquisition time was 12-14 minutes. Before imaging of each partition one NAV-echo was sampled with the same acquisition parameters as for imaging. After data acquisition, the NAV-echos (= non phase encoded echos) were 1D-fourier transformed and a least squares fit was performed to determine diaphragm position. Based on the most frequently-occuring diaphragm position an accept/reject window was defined, and image data within this window was reconstructed (navigator efficiency ~35%).

Results: Figure 1 shows the acquired NAV-echo projections of a volunteer (experiment A). In figure 2 the corresponding time course of diaphragm movement and the cardiac cycle is depicted. Signal drop in the lower plot of Figure 2 corresponds to the systolic phase of the heart cycle, where the heart contracts rapidly. Due to the large signal differene between the systolic and diatolic phase, triggering to the heart beat is possible. Figure 3 depicts one slice of a reconstructed 3D gradient echo dataset (experiment B). Even near the diaphragm, image quality (resolution) is high, demonstrating that the determination of the diaphragma position is accurate. Furthermore, no degration of image quality is visible in the entire volume due to saturation effects of the NAV-echo.

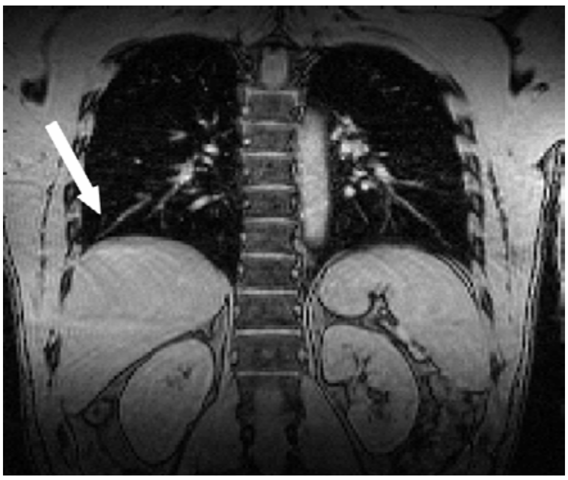
Figure 3: One slice of a 3D gradient echo dataset. Even near the diaphragm, blood vessels are clearly visible.

Conclusion: High resolution lung imaging during free breathing is possible using globally acquired projections along the head foot direction over the entire thorax volume. Not only respiratory but also cardiac triggering can be performed using this NAV-echo procedure. As no breath-hold is required, and no external devices are needed for imaging, this technique allows easy examinations of patients. In the future, this method will be used for prospective motion correction, which shortens the total imaging time and allows to acquire datasets with high resolution in moderate examination times. Furthermore, this technique is not only restricted to morphological imaging, and can be adapted for functional imaging as well.

Referenes:
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3) Felmlee, JP, et al, Radiology. 1991 Apr; 179(1):139-42.