Comprehensive Signal-Time-Course Scanning

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Introduction:

Perfusion scanning and evaluation with MRI in multiple organs gains increasing interest. Some of the conventional methods for abdominal imaging use the application of a contrast agent. During the arrival time and first pass of the tracer in the volume of interest rapid signal changes can be observed requiring a high temporal sampling of images. Instead of using time consuming motion corrections during that scan period, patients are asked to keep the breath as long as possible to reduce signal modifications caused by respiration. Since characteristic signal changes last longer than breath-holding or reveal useful information over a longer time interval, it is necessary either to scan during free breathing or to repeat the breath-hold measurement. Luckily, the temporal changes of the tissue signal after the first pass are much slower. The methods for correcting the effects of motion differ depending on the sequence techniques. A 3-dimensional scan provides the option for co-registration of the partial tomograms in 3 spatial dimensions, although this scan is susceptible to motion blurring or its resolution is very limited. A 2-dimensional scan may provide better in-plane resolution or is virtually freezing the motion of the organ, but shifs in slice direction can't be corrected easily.

Methods:

Based on our assumptions and experiences of motion correction in body imaging we implemented a navigator echo technique with multiple modes combined with different gradient or spin echo readout modules. Different sequential phases are used: *Phase 1*. The learning phase, when the characteristic respiratory motion of the diaphragm is measured over several respiratory cycles, and the location of the acceptance window is calculated. *Phase 2*. The breath-hold phase, when multiple measurements are performed without interruption and navigator scans. The highest image sampling rate is realized depending on the sequence parameters. *Phase 3*. The trigger phase, when the navigator scans are resumed automatically and imaging is further on triggered by the respiratory motion based on the results of the learning phase and the actual diaphragm position. The learning cycles, the measurements during breath-hold, the slices for triggering and several other characteristic numbers and parameters can be adjusted to meet specific requirements for scanning tissue perfusion and analyzing the signal time evolution.

Experiments and Results:

The above described method was performed in combination with a saturation prepared FLASH sequence for renal perfusion and with a saturation prepared TrueFISP sequence for liver perfusion. The repetition time of the navigator scans was 150 ms. The learning phase used 5 respiratory cycles. The acceptance window was adjusted close to the median of the end-expirational positions of the diaphragm with ± 2 mm width. A breath-hold command was given and patients were asked to keep the breath in expiration over a comfortable time period at least. Although this breath-holding in expiration is not the most convenient exercise, we found this position to be the most reproducible, providing a consistent longer time interval of low motion during a multi-slice scan. After contrast agent injection, the imaging scans were started manually turning off navigator scanning. The number of measurements during the breath-hold covered the signal slope during the first pass completely. Afterwards the navigator scanning was resumed automatically to measure the respiratory motion and trigger the imaging scans. The sampling rate of the signal was determined by the physiological respiration period during that phase. We scanned 3 and 4 slices per respiratory cycle, each image within 250 and 300 ms, respectively.

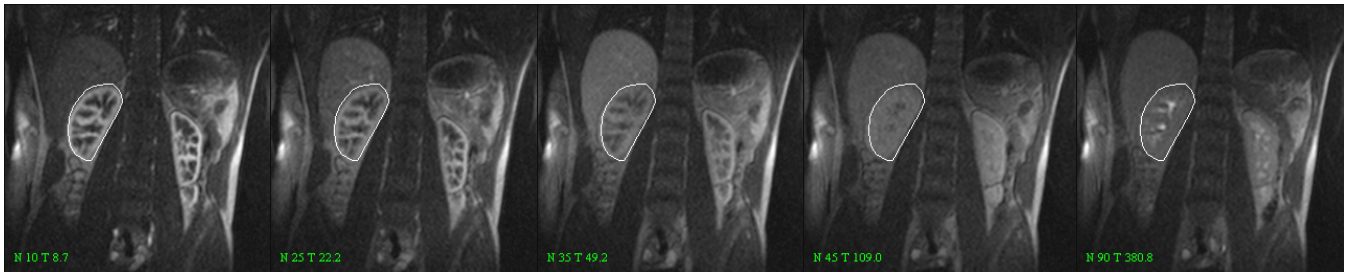

Figure 1: Comparison of positions of the right kidney at different time points (N image number, time T in sec).

Discussion:

This combination of breath-hold and respiratory triggered acquisition makes it possible to observe the signal time changes of a tissue after contrast agent injection with one sequence protocol and adapted temporal resolution over a time period much longer than a respiratory cycle. The organs are displayed at a constant respiratory position, which mainly reduces the problem of in-plane and through-plane motion. Figure 1 shows image examples from a renal perfusion scan at different times after start. The location of the white contour is constant in order to compare the relative position of the right kidney at different time points more easily. Small variations of the positions can be observed due to the finite resolution of the navigator scan and the size of the acceptance window for triggering. Those in-plane translations are corrected by post-processing methods easily if a regional specific signal time analysis is performed. The number of slices per respiratory cycle needs to be adapted to the available period of reduced respiratory motion.