Reduction of Breathing Motion Artifacts in Shoulder Imaging using an Orbital Navigator as Motion Sensor

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Introduction   Motion during image acquisition can cause serious image artifacts. In the shoulder, subtle breathing motion as well as incidental displacements are sources of motion artifacts. With the trend towards higher spatial resolution, the relatively small displacements due to normal breathing are becoming more significant. Here, we demonstrate an artifact reduction method which can be applied to a clinical imaging protocol and 1.) uses an orbital navigator (onav) signal [1] to sense the breathing motion and 2.) uses a reconstruction from a reduced dataset to improve image quality. The motion signal from the navigator is used to control which data are used in the reconstruction.

Materials and Methods   Acquisition: All experiments were performed with volunteers on a clinical 3T scanner using a four channel shoulder coil. A standard T1-weighted, fast spin echo sequence was adapted to include the orbital navigator as the first echo of the echo train: TR/TE 625/20 ms, echo train length 4, FOV 130x120 mm, voxel size 0.43x0.53 mm, 20 slices, slice thickness 2.5 mm. Interleafs were acquired in random phase encoding order. The volunteers were instructed to lie still and breathe normal.

Motion signal calculation: From the navigator data, the two orthogonal in-plane translations s_x and s_y were estimated for each interleaf by fitting a rigid motion model to the navigator signal [2]. Both values were combined into a total shift $s_t = (s_x^2 + s_y^2)^{1/2}$ to use the navigator signal as a motion sensor. Total shift values from different slices were combined into a single value by a weighted average. The averaging weights were inversely proportional to the residual of the motion model fit. This weighting scheme stabilized the combined motion signal by reducing the influence of slices where pulsatile motion is dominant, on the combined motion signal.

Reconstruction: We used an iterative SENSE reconstruction [3] using only data from interleaves with a total shift $s_t < 0.2$ mm to reconstruct the final image. The iterative reconstruction was initialized with a standard SENSE image using the full data set.

Results   Motion sensing: Figure 1 shows an example of an orbital navigator derived motion signal. The motion signal was influenced by different types of motion: a) breathing motion which occurs quasi-periodically and could be described well by a rigid translation. b) Pulsation from vessels, which appeared as random disturbance of the navigator signal and could not be described by the rigid motion model. These were only present in slices containing big vessels. c) Occasionally, larger non-periodic motions which could be described by translations were observed (see Fig. 1, around 50 s). These are probably due to twitching.

Reduction of image artifacts: Fig. 2a and 2b show image reconstruction results using the full dataset and a reduced dataset, excluding corrupted profiles, respectively. Using only the sub-set of the acquired data where the motion was less than 0.2 mm reduced ghosting artifacts and blurring significantly. On the other hand, signal-to-noise ratio decreased disturbingly if the amount of rejected data was more than approx. 30% of the full dataset or the distribution of rejected data in k-space was unfavorable. Acquiring interleafs in a random order was used as a simple and effective way to mitigate the latter problem.
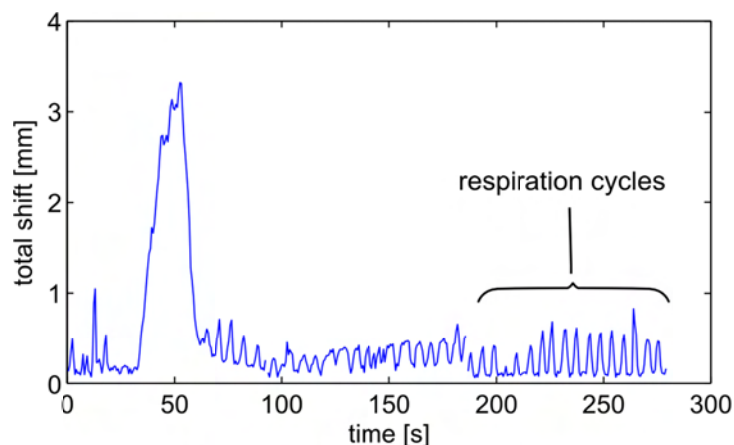

Figure 1: Onav displacement sensing during a multi-slice TSE exam.

Figure 2: a) uncorrected reconstruction using full TSE data, b) iterative SENSE reconstruction using only onav selected data sub-set.

Conclusion   A significant reduction of breathing motion artifacts could be achieved by using only a sub-set of data in the reconstruction. Selection of the sub-set was based on a motion signal derived from an orbital navigator which was added to a standard TSE sequence causing only a minimal increase of scan time.

References   [1] Fu, et al., MRM 34: 746-753, 1995;   [2] Ward, et al., MRM 43: 459-469, 2000;   [3] Samsonov, et al., MRM 52:1397-1406 2004