Navigator-Guided Data Reacquisition for Motion Artifact Reduction

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Purpose: Motion during MR data acquisition can cause artifacts which compromise the diagnostic value of images. In T2w fast spin echo imaging of the brain, motion artifacts are typically due to bulk head movements, pulsation or incidental motion (eye movement, swallowing or coughing etc.). Purpose of this study is to reduce motion artifacts by identifying data inconsistencies caused by motion and replacing the motion corrupted part of the data set with reacquired and improved data [1,2].

Methods: To quantify data inconsistency in real-time, an orbital navigator echo [3] was added as the first echo to each interleaf of a fast spin echo sequence (TR/TE 2200/100 ms, ETL 15, matrix 256). The difference between the navigator data of different interleafs is taken as a measure for data inconsistency. Two questions were investigated in this study:
1.) How are the navigator fluctuations correlated with the level of image artifacts, and
2.) Can image artifacts be reduced by reacquiring parts of the data set - where the decision which interleafs are reacquired is based on the navigator signal.
The first question was addressed by a simulation study: Image and navigator data from a volunteer experiment without motion were used as reference. The effects of in-plane translations in the range of 0 to 2 pixels were simulated by appropriately modulating the phase of the image and navigator data, respectively. Images were reconstructed from these motion corrupted data sets and compared to the motion-free reference image. The ghosting artifact level was quantified by the L_2 norm of the image difference divided by the L_2 norm of the reference image. The correlation between artifact level and average navigator difference was investigated for different motion patterns: incidental motion, which disturbs only 2 out of 15 interleafs, and random motion affecting all interleafs. The translation was applied in the read-out and phase-encoding direction, respectively.
The second question was addressed by adding a data reacquisition period to the end of the nominal data acquisition period: During the reacquisition period, always that interleaf with the biggest navigator deviation was selected for reacquisition. The duration of the reacquisition period was 25% of the regular scan time.
The feasibility of the artifact reduction method was tested with 6 healthy volunteers using a clinical 1.5T scanner (Philips Achieva) with an 8 channel head coil. To investigate the ability to correct for different sources of artifacts, the volunteers were asked to perform different types of motion (swallowing, coughing, eye rolling/blinking) at a random point in time during the scan. A scan without deliberate motion was acquired for reference purposes.

Results and Discussion: Figure 1 shows that there is a high correlation between average navigator difference and image ghosting level which is largely independent on the type or direction of motion. This implies that it is possible to predict the level of ghosting artifacts from the distribution of navigator data before an image is reconstructed. Furthermore, a best-case estimate of the trade-off between image quality improvement and additional scan time can be obtained by repeatedly calculating the average navigator difference while successively removing the worst navigator from the set. In general, the shape of this trade-off curve will be non-linear and depend on the actual motion that was present during the scan.
The navigator signal is highly sensitive to all types of motion which were investigated. Even subtle variations caused by pulsation are picked up by the navigator signal. This was verified by correlating the navigator fluctuations (from scans without motion) with a pulse-oxymeter signal.
Fig. 2 shows two examples of how reacquisitions can improve image quality: Shown are the images without reacquisition, with reacquisition and the difference. The top row is from a scan during which the volunteer coughed slightly, the bottom row from a scan during which the volunteer swallowed. In both cases, the artifacts are removed by the navigator-guided reacquisition.

Conclusion: Navigator fluctuations and image artifact levels are highly correlated. Navigator-based data reacquisition offers an elegant way to improve the robustness of image quality against different types of incidental motion.

References
[1] Sachs, et al., MRM **34**, 412-422 (1995)
[2] Barral, et al., MRM **66**, 174-179 (2011)
[3] Fu, et al., MRM **34**, 746-753 (1995)

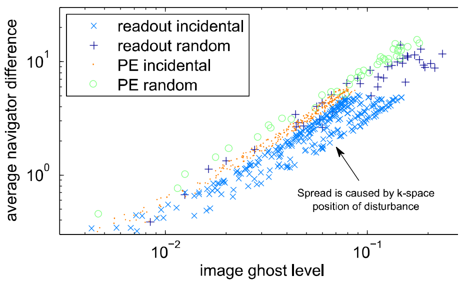

Figure 1: Correlation between image ghosting and average navigator difference (PE denotes the phase encoding direction).

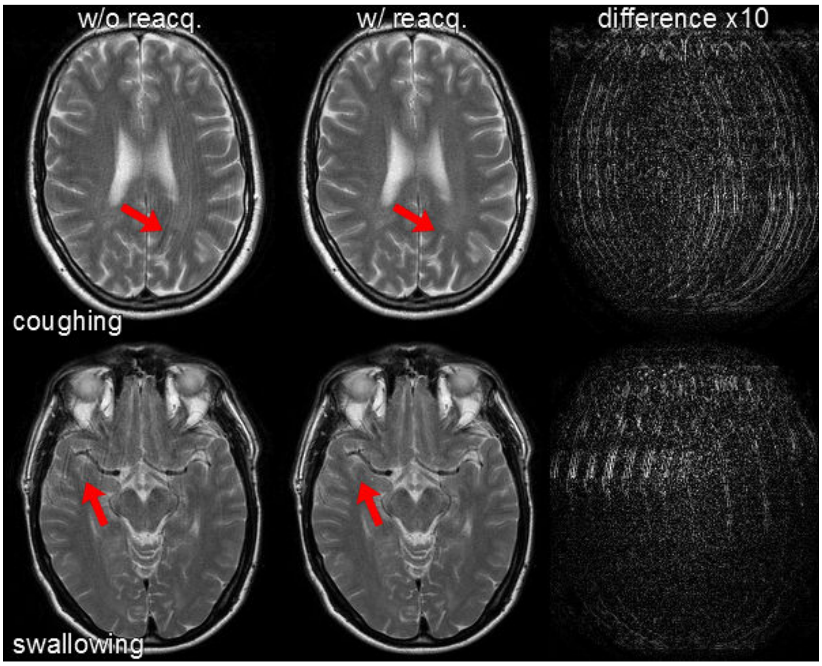

Figure 2: Comparison of image quality without reacquisition (left) and with reacquisition (middle). The right column shows the difference x10.