

Comparison of quantitative artifact level in TGRAPPA and TSENSE reconstruction during deep breathing

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Introduction: The rapid heart rates and deep breathing encountered during exercise or dobutamine stress MRI make it difficult to achieve the necessary spatial resolution, temporal resolution, and image quality with real-time cine techniques. Parallel imaging has enabled improved temporal resolution, but at the cost of increased artifact and noise. Temporal resolution can be further improved by reducing FOV in the phase encoded direction. However, in the case of deep breathing such as during or after exercise, the chest wall can move in and out of the FOV causing aliasing. GRAPPA, a k-space-based reconstruction method, is known to be less sensitive than SENSE to these effects [1]. Surface coils can also move with deep breathing, causing a mismatch between the coil sensitivity map and the actual coil position, another potential source of artifact [2]. While physician-assigned qualitative scoring is typically used to evaluate these artifacts, it is subjective, time-consuming, and impractical for large data sets. To overcome this challenge, we propose to quantify parallel imaging artifacts by exploiting their spatially fixed nature and examining the peak of the autocorrelation function applied to the image series. Our hypotheses are that the autocorrelation function can accurately quantify parallel imaging artifacts, and that TGRAPPA will perform better than TSENSE in terms of artifact level under the condition of deep breathing that causes aliasing and coil sensitivity map errors.

Objective: To quantitatively compare the artifact performance of TGRAPPA and TSENSE reconstruction under the condition of deep breathing using an autocorrelation-based approach.

Methods: We acquired cine series in three views (short-axis, vertical and horizontal long-axis) in 5 healthy subjects during deep breathing using SSFP real-time cine accelerated 3-fold with TSENSE and TGRAPPA on a Siemens 1.5T Avanto, resulting in a total of 30 image series. Sensitivity maps were obtained by interleaving and averaging all undersampled frames in each series. Scan parameters were: TE/TR 0.9/2.2ms, average FOV 374x299mm, matrix 160x84, and temporal resolution 63.8±1.6ms. The FOV was specified immediately adjacent to the chest wall in the view in which the body appears largest in the phase encode direction (typically the VLA). Artifacts were quantitatively analyzed by examining peaks in the image autocorrelation function in the phase encode direction at shifts of 1/3 and 2/3 FOV, the expected locations for parallel imaging associated ghost artifacts at rate 3 acceleration. Within each series, the highest 10% of autocorrelation coefficients at 1/3 FOV were averaged to define an “artifact index”. In addition, two experienced readers blinded to the study assigned qualitative scores of artifact severity: (1) none, (2) minor, (3) moderate, and (4) severe.

In order to isolate the effect of coil sensitivity mismatch from FOV aliasing, we performed measurements in 3 healthy subjects in the liver to exclude the effects of cardiac motion. In the baseline case, an accurate coil sensitivity map was maintained throughout the scan by breath-holding. In the second case, the coil sensitivity map was acquired at peak inspiration at the start of the scan while the remaining data was acquired during end-expiratory breath-hold to create a mismatch between the acquired and actual coil sensitivities. We reconstructed each data set using both TSENSE and TGRAPPA.

Results: In the real-time SSFP cine images, TGRAPPA was superior to TSENSE in terms of the physician-assessed artifact severity (1.7±0.6 vs. 2.9±0.8, p<.001). Figure 1 illustrates the increased artifact level with TSENSE compared to TGRAPPA. The artifact index obtained with the autocorrelation function agreed with the qualitative artifact scores, with TGRAPPA showing less artifact severity (0.058±0.035 vs. 0.110±0.052, p=.0036). Figure 2 displays the higher autocorrelation coefficient for TSENSE vs. TGRAPPA at 1/3 and 2/3 FOV. In addition, TSENSE exhibited greater artifact severity and a greater artifact index in the liver images acquired under the condition of coil sensitivity mismatch (Figure 3). The artifact index was greater with TSENSE than TGRAPPA in each case, although the difference was not statistically significant.

Conclusions: We demonstrated the utility of a novel approach for quantifying parallel imaging artifacts by exploiting their spatially fixed nature to determine peaks in the autocorrelation function and obtain an “artifact index”. Both quantitative and qualitative scores showed that TGRAPPA delivered superior artifact performance compared to TSENSE in the presence of deep breathing. In addition, preliminary results indicate that TGRAPPA exhibits less sensitivity to coil map errors even without aliasing in the reconstructed FOV, but more data is required to draw statistical conclusions. While SENSE provides an optimal reconstruction under normal conditions of breath-hold or quiet breathing, our results demonstrate that it suffers from artifacts when the FOV is smaller than the object or the coil map is imperfect, such as under exercise stress, deep breathing, and patient motion.

[1] M. A. Griswold, S. Kannengiesser, R. M. Heidemann, J. Wang, and P. M. Jakob, *Magn Reson Med*, vol. 52, pp. 1118-26, 2004.
[2] F. A. Breuer, P. Kellman, M. A. Griswold, and P. M. Jakob, *Magn Reson Med*, vol. 53, pp. 981-5, 2005.

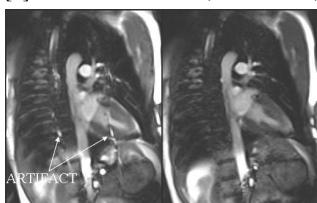


Figure 3: Increased artifact level of TSENSE (left) vs. TGRAPPA (right) under deep breathing

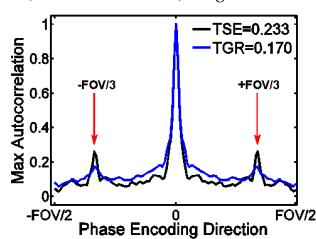


Figure 2: Autocorrelation function

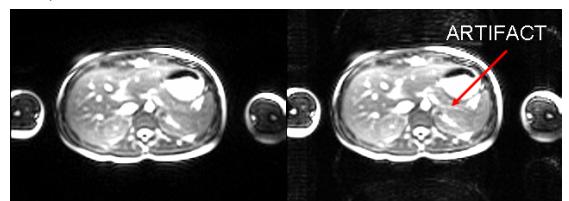


Figure 3: Liver images illustrating the increased TSENSE (right) artifact due to coil map mismatch compared to TGRAPPA (left)