

Auto-Calibrated Parallel Imaging Using the Unused Echo in Alternating TR SSFP

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Introduction Parallel imaging uses spatial information from a multiple receiver coil array to reduce the required number of gradient-encoded k-space lines [1-3]. Accurate coil sensitivity information is crucial for robust reconstruction of the under-sampled datasets; this information can be directly obtained by acquiring full-FOV low-resolution k-space lines in the central region of k-space. A number of auto-calibration approaches have been demonstrated which extract real-time coil sensitivity information by variably sampling the k-space [4,5].

Alternating SSFP contains two distinct repetition times [6,7]: one longer TR for image acquisition, and one short TR (TR_s) added primarily for establishing a beneficial spectral response. No data is acquired in the short TR because its duration is usually insufficient for the acquisition of a full k-space line along the readout direction. However, it is possible to acquire a smaller k-space matrix during TR_s , which allows for calibrating parallel imaging reconstruction kernels. In this study we proposed to obtain auto-calibration signal in the short TR of a wideband SSFP cardiac sequence and used it for GRAPPA reconstruction of cine images acquired in the long TR.

Methods In-vivo 2D wideband SSFP cine scans were performed in healthy volunteers on a GE Signa Excite (GE Healthcare, Waukesha) 3T scanner with an 8-channel cardiac receive coil array. 2DFT readout was used with parameters: $FOV = 30 \times 30 \text{ cm}^2$, in-plane resolution = $1.2 \times 2.3 \text{ mm}^2$ (256×128 acquisition matrix), slice thickness = 8 mm, flip angle = 30° , $TR/TR_s = 3.6/2.4$ ms for wideband SSFP. ECG gating was used for a total breath-hold time of 8 RR intervals. Reduction factor (R) = 2 images were also obtained with doubled temporal resolution (96 ms and 48 ms for full k-space and $R=2$ cine scans, respectively). For each cardiac phase, a dataset with a smaller k-space extent (64×64) containing auto-calibration signals (ACS) for each cardiac phase was acquired during TR_s (See Figure 1). Four anterior coil elements were considered for the GRAPPA reconstruction. GRAPPA kernels were estimated using the TR_s data only, and were used to reconstruct missing k-space lines in long TR dataset.

Results and Discussion Figure 2 shows sample systolic and diastolic wideband SSFP images obtained from a breath-held cine scan. The first column on the left shows the full k-space reference images. The second column contains aliased images from an $R = 2$ scan. The third column contains the low-resolution images reconstructed from the echoes in TR_s . The column on the right contains the images after the GRAPPA reconstruction. Aliasing artifacts were substantially removed in the region of interest in the GRAPPA-reconstructed images with exactly twice the temporal resolution. Note that the ACS images acquired in TR_s exhibit much higher SNR and different image contrast compared to the image in the long TR, but the GRAPPA reconstruction still performed properly since the estimation of coil sensitivity weighting for GRAPPA kernel doesn't depend on image contrast.

Conclusion We demonstrated auto-calibrated parallel imaging using wideband SSFP sequences without acquiring auto-calibrating lines during additional long TR. Doubled temporal resolution was achieved with $R = 2$ GRAPPA reconstruction. This method can also be used to shorten the required breath-hold time and reduce the artifacts caused by subject motion during the scan.

References [1] Sodickson *et al.*, MRM 38:591 (1997); [2] Pruessmann *et al.*, MRM 42:952 (1999); [3] Griswold *et al.*, MRM 47:1202 (2002) [4] Jacob *et al.*, MAGMA 7:42 (1998); [5] McKenzie *et al.*, MRM 47:529 (2002); [6] Leupold *et al.*, MRM 55:557 (2006); [7] Nayak *et al.*, MRM 58:931(2007)

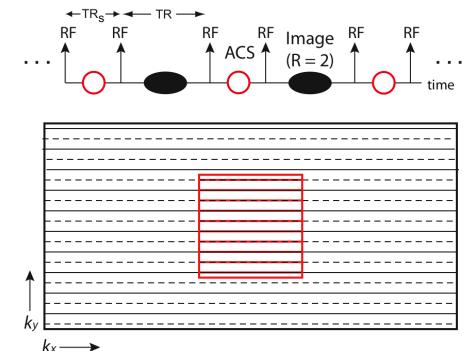


Figure 1 An alternating TR sequence with acquisitions in both repetition times. The black ellipses represent the acquisitions of the high-resolution images in TR. The red circles and the red lines in the bottom k-space represent the acquisitions of ACS lines in TR_s . Solid black lines represent the acquired lines, and the dashed lines represent the missing data.

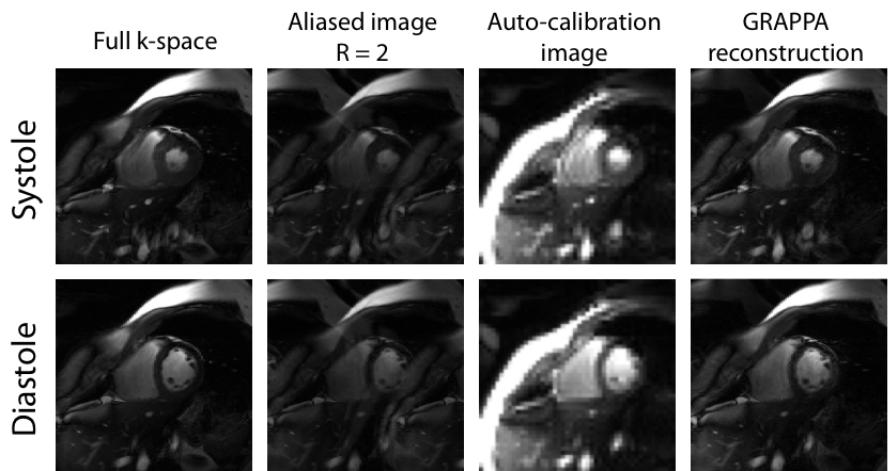


Figure 2 End-of-systole and end-of-diastole images of 8 RR cine scans. For an $R = 2$ scan, GRAPPA reconstruction successfully removed aliasing artifacts from the regions of interest using signals from four coil elements and ACS information obtained in TR_s .