View Ordering in GRAPPA Fast Spin-Echo Methods

A. Krishnan[1], Z. Li[1], A. Bilgin[1,2], M. I. Altbach[2]

[1]Dept. of Electrical and Computer Eng., University of Arizona, Tucson, AZ, United States, [2]Department of Radiology, University of Arizona, Tucson, AZ, United States

Introduction: Parallel imaging techniques are used to increase the speed of image acquisition in MRI[1-5]. These techniques typically require the acquisition of only a fraction of the phase encoding lines necessary to reconstruct a full FOV image. The spatial sensitivity information of each coil is then used to reconstruct the missing information. Recently, parallel imaging techniques with auto-calibration capabilities have been introduced[2,4,5]. These techniques acquire additional phase encoding lines to be used for auto-calibration and do not require a separate calibration scan to estimate the coil sensitivities. The additional auto-calibration scan (ACS) lines are fit to the lines in the reduced dataset and the weights that result from the fit are used to reconstruct the missing lines.

So far, auto-calibration parallel imaging methods, such as the Generalized Autocalibrating Partially Parallel Acquisitions (GRAPPA)[5], have been demonstrated on data acquired with MRI methods where the signal weighting is relatively constant through k-space. For these cases it was demonstrated that locating the ACS lines in the center of k-space results in better fits and reduced artifacts since the center of k-space can be measured more accurately due to higher SNR. Furthermore, since the missing lines at the center of k-space are acquired as ACS lines, these lines don't need to be estimated and can be included in the final reconstruction to avoid low-frequency, high-energy artifacts. If the MRI method, however, is based on the acquisition of k-space lines with different signal weighting, as in fast spin-echo (FSE) imaging, the placement of ACS lines must take into account the differences in signal weighting. In this work we study the effects of auto-calibrated parallel imaging in FSE data and propose a view ordering scheme that minimizes artifacts due to the differences in signal weighting caused by T2 decay.

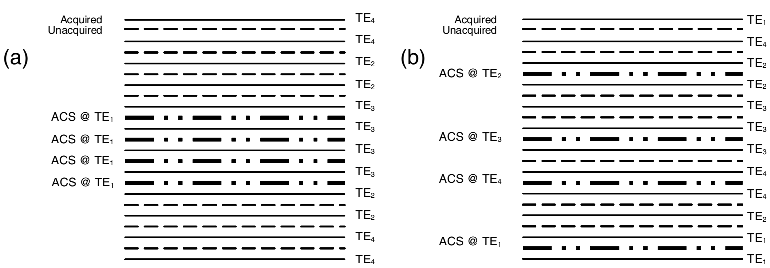

Fig. 1: Different strategies for view ordering of the ACS lines

Methods: To explore the effects of the acquisition order of the ACS lines, a regular FSE pulse sequence was modified to acquire GRAPPA data with an acceleration factor of 2. Two view ordering schemes were implemented. In the first scheme, the first echo of each TR period was used to acquire an ACS line (i.e. ACS lines acquired at TE_1). These ACS lines were placed in the center of k-space regardless of the TE_{eff} (Fig. 1a). The ordering of the remaining (non-ACS) lines was the same as in a regular FSE sequence. In the second scheme, the acquisition order was modified such that the ACS lines are distributed throughout k-space (Fig. 1b). The locations of the ACS lines were selected such that the ACS lines are at the same TE as the neighboring lines. In both cases, the reduced dataset were fit to the ACS lines to obtain the GRAPPA weights. These weights were used to reconstruct the missing lines for each coil using a block size of 6. The individual coil images were then combined using the sum-of-squares method.

The GRAPPA FSE method was implemented on a 1.5 T GE Signa scanner. A four-channel phased-array torso coil was used for signal detection. Data were acquired with ETL=7 and 98 views. The echo spacing (time between 180^o RF pulses) was 15 ms so the T2 decay of the acquired data span a range of 15-105 ms TE values. Data with either view ordering scheme were acquired over 14 TR periods. Thus for the view ordering scheme shown in Fig. 1a, 14 ACS line were acquired with the signal intensity weighted to TE_1. For the view ordering scheme shown in Fig. 1b, 21 ACS lines were acquired over the 14 TR periods. The signal weighting of these ACS lines samples all TE values (i.e., three ACS lines per TE).

Results and Discussion: Images obtained with the view ordering schemes shown in Fig. 1 are shown in Fig. 2 for a phantom and in-vivo data. With the view ordering scheme shown in Fig. 1a there are residual artifacts (as pointed by the *arrows*) due to the inconsistencies in signal weighting (i.e. different TEs) between the ACS and the acquired lines. These artifacts are significantly reduced if the signal weighting of the ACS lines is matched to the acquired lines as is the case for the ordering scheme shown in Fig. 1b. It should be pointed out that in the data acquired with the method of Fig. 1b there were 7 fewer non-ACS lines compared to the data acquired with the method of Fig. 1a. This results in a slight decrease in image resolution. The slight decrease reduction in spatial resolution is clearly offset by the reduction in image artifacts.

Conclusion: It was demonstrated that GRAPPA with FSE is feasible but the location of the ACS lines is very important. In most cases the acquisition of ACS lines in FSE only requires a modest extension of the ETL, which makes the method very efficient in terms of imaging time. The principles presented here can be extended to other pulse sequences where k-space lines are acquired with different signal weighting.

Acknowledgements: Work supported by NIH (CA099074) and the American Heart Association (0355490Z).

References: [1] Sodickson et al, MRM, 38, 591 (1997) [2] Jakob et al, MRM in Phys, Bio and Med, 7, 42 (1998) [3] Preussman et al, MRM, 42, 952 (1999) [4] Heidemann et al., MRM, 1065 (2001) [5] Griswold et al, MRM, 47, 1202 (2002)

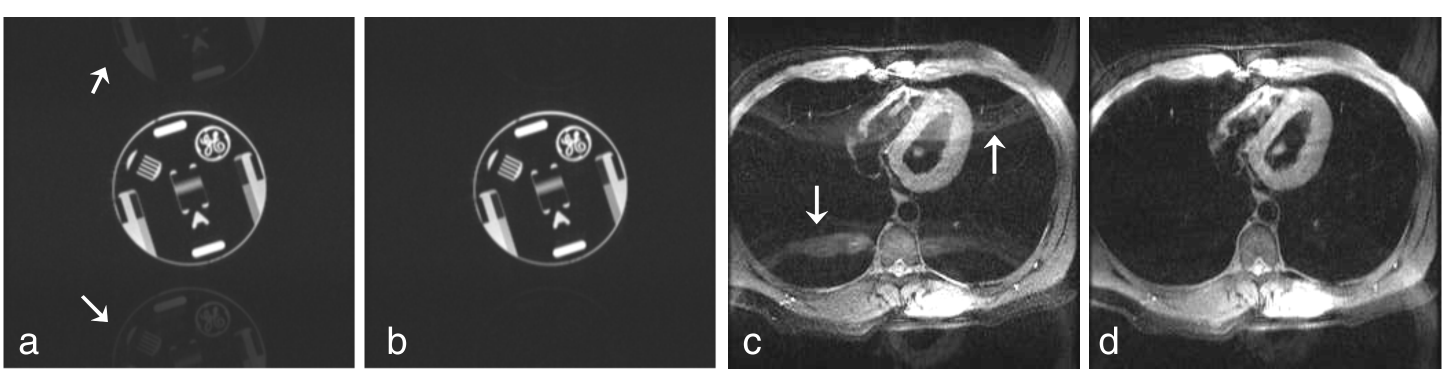

Fig. 2: Fast spin-echo images obtained using the two techniques. The images in (a) and (c) were acquired using the view ordering in Fig. 1a, and the images in (b) and (d) were acquired using the view ordering in Fig. 1b.