Potential Pitfalls of Including Reference Data in Parallel Imaging Reconstructions at High Acceleration

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Introduction

GRAPPA[1] is an "auto-calibrating" parallel imaging reconstruction technique. In GRAPPA, several center k-space lines (ACS, Auto Calibration Signal) are acquired, in addition to the down-sampled dataset. ACS lines are used to determine coil-weighting factors and can be included directly in the reconstruction to improve image quality. Park et al. [2] proposed shifting the calibration region to higher frequencies in the PE direction, instead of using the center region as the calibration region. This modification can improve overall image quality, but as shown here at high acceleration factors, can create shading and blurring of the image. Adding center reference data can reduce the appearance of these artifacts, and we are systematically investigating the role of calibration and center regions on image quality.

Methods

The calibration region shift method [2] was implemented in Matlab. The center and calibration regions (Figure 1) were detached in the reconstruction. The calibration region is only used for calculating the coil-weighting factors, and the data are not integrated into the final reconstruction. It includes two symmetrical regions in positive and negative k-space. The data in the center region are only used for replacing the corresponding reconstruction data to improve image quality. The calibration and center regions are independent and can overlap. Several different positions and widths for these areas were tested at high accelerations by decimating two fully sampled data sets to simulate an actual reduced acquisition. The first brain dataset were acquired from a 4-channel coil, 256x256 in matrix size, and reconstructed with ORF (Outer reduction factor) = 4. The second cardiac dataset was acquired from an 8-channel coil, 209x256 in matrix size, and reconstructed for ORF = 6.

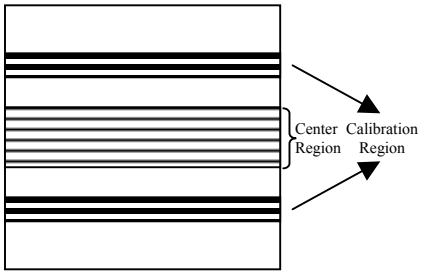

Figure 1. The additional acquired k-space lines lied into two regions, a center region which is only used to replace the final reconstructed matrix, and a calibration region which is only used to calculate the coil-weights.

Results

The results are shown in Figure 2. Reference images are shown in the right column (d and h). The rest of the images are reconstructed with the same calibration region (schematically shown as dark vertical lines to the right of each image), and different center regions (gray regions in the center of the white bars). The number of lines in the center region is 0 (a and e), 10 (b and f) and 40 (c and g). The key feature of these images is that at this high acceleration, the parallel imaging reconstruction essentially fails, resulting in significant artifacts. Adding center lines reduces the appearance shading artifact as the number of center lines varies from 10 to 40. However, in regions where there is no signal in the pure-reconstructed image (a&e), the resolution is essentially limited by the number of center lines included in the reconstruction, resulting in significant blurring when only a few lines are included. This is however still evident even when 40 lines are included in the reconstruction, as shown in (c). This blurring is probably a greater issue in clinical applications requiring fine detail (brain) than in other applications such as cardiac imaging where speed is of the essence.

Discussion

We found that calibration region shift does help with the image quality comparing with the regular GRAPPA (Results not shown here), but recommend not including reference data into the final image at high acceleration factors. The previously described shading and blurring artifacts brought about by the reconstruction could be concealed by the normally incorporated center reference data, and the residual artifacts could be "misleading" for a high-quality image required application, such as tumor detection in human brain.

Conclusion

One should be careful when incorporating reference data in a GRAPPA reconstruction, in particular at high acceleration factors.

Reference:

[1] Griswold M, et al., MRM 47:1202–1210, 2002. [2] Park J, et al., MRM 53:186-193, 2005

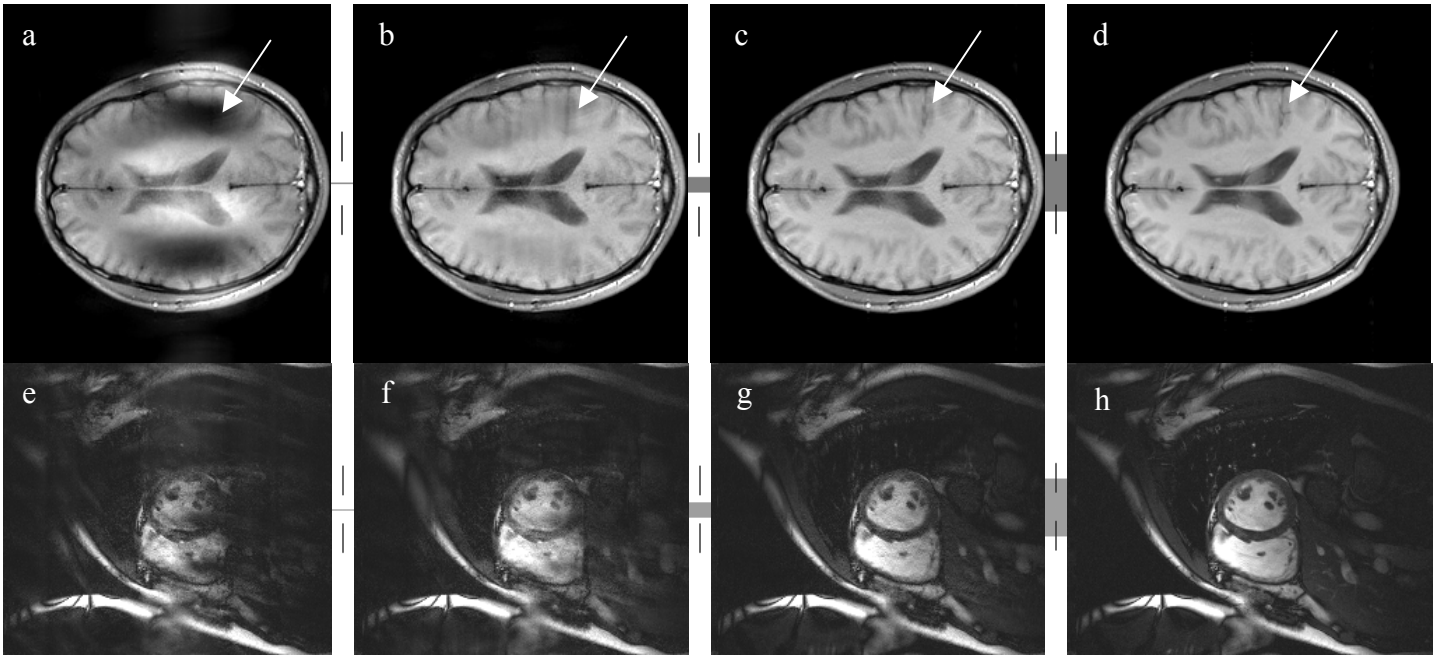

Figure 2. The effects of including center reference lines into the reconstruction. Head images (upper) and heart images (lower) with different number of center lines are shown. The first column from the right are the reference images reconstructed from the full-sampled data. The rest of the images are reconstructed with 0 reference lines (a and e), 10 reference lines (b and f), and 40 lines (c and g). The vertical bar on the right of each image represents the calibration and center region as explained in the text.