DIR imaging using GRAPPA for Cortical thickness estimation

N. Choi[1], Y. Nam[1], and D-H. Kim[1,2]

[1]Electrical and Electronic Engineering, Yonsei University, Sinchon dong, Seoul, Korea, Republic of, [2]Radiology, Yonsei University, Sinchon dong, Seoul, Korea, Republic of

Introduction

Most gray matter volumetric studies use T1-weighted imaging such as MP-RAGE because it provides good contrast between white matter and cortex. However, due to susceptibility artifact coming from the air-tissue interface (Fig. 1), a reliable and accurate measurement is difficult in the regions near the air-bone interface for T1-wieghted schemes. One way to alleviate this problem is to perform gray matter spin-echo imaging through double inversion recovery (DIR) sequence. The sequence selectively suppresses the signal from cerebrospinal fluid (CSF) and white matter using two inversion recovery pulses [1]. One drawback of the DIR sequence, however, is its long scan time. For high resolution 3D DIR imaging, orders on the order ±20 minutes can be required for full k-space coverage. This can be effectively reduced by using from a variety of parallel imaging schemes. The objective of this study was to determine the influence of undersampling with parallel imaging on cortical thickness measurements using a DIR acquisition scheme. Here, we applied one of the parallel imaging reconstruction schemes, namely, the Generalized Autocalibrating Partially Parallel Acquisition (GRAPPA) [2] scheme to DIR imaging to evaluate measurement changes as a function of reduction factor.

Methods

Seven healthy volunteers (4 male and 3 female; age 24.6±2.15 years) underwent MRI using 3D DIR sequence at 3.0T Siemens Tim Trio MRI scanner. The scan parameters were as follows: FOV = 256 mm, TR = 10000 ms, TE = 207 ms, TI1 = 3651.7 ms (interval between first and second inversion pulses), TI2 = 551.7 ms (interval between second inversion and excitation pulse), slice thickness = 1.0 mm, voxel size = 1.0x1.0x1.0 mm, coverage of 25.6 cm x 25.6 cm x 17.8 cm, total scan time = 24 min 2 sec for 100% k-space 3D coverage.

GRAPPA simulations were performed from the full data set for three different reduction factors (2, 3, and 4). The number of ACS (auto-calibrate signal) lines used were 12, 16, and 18, respectively. Simulations and data reconstruction were performed using MATLAB R2007b.

Freesurfer v.4.3.0 (MGH, Harvard, http://surfer.nmr.mgh.harvard.edu), a widely used software for cortical thickness measurement, was used to evaluate the cortical thickness of the entire brain. The global cortical thickness was compared with various reduction factors by using an one-way ANOVA test in SPSS.

Result

Fig. 2 shows images reconstructed with GRAPPA factors two and three. The outer red line indicates the gray matter/pial surface boundary and the yellow line surrounds the gray/white matter boundary. Although reduced SNR and blurring are observed for increased reduction factor, in terms of segmentation the effect was not so significant. However, further increasing the reduction factor to R=4 had aliasing artifacts that was not appropriate for volumetric studies. The volumetric result that uses Freesurfer is as follows. It was validated that there were no significant differences in many cortical regions (17 out of 34 for p>0.05 and 11 for p>0.10, see Table 1). Images on the left (top and bottom) in Fig. 3 represent cortical thickness difference between reference and R=2, and images on the right (top and bottom) represent thickness difference between reference and R=3. Regions shown in blue represent underestimated cortical thickness, and yellow-red regions represent overestimated cortical thickness.

Table 1. Statistical values

ROI name	F(df)	p-value
frontalpole	1.704	0.210
superiortemporal	2.001	0.164
rostralanteriorcingulate	0.186	0.831
superiorparietal	3.245	0.063
caudalanteriorcingulate	1.930	0.174
Isthmuscingulate	1.225	0.317
temporalpole	1.013	0.383
parsorbitalis	1.417	0.268
Insula	1.106	0.352
parsopercularis	1.426	0.266
entorhinal	1.088	0.358

(a) MP-RAGE image (b) DIR image
Figure 1.
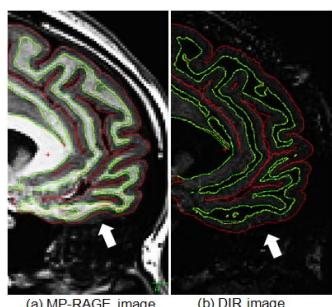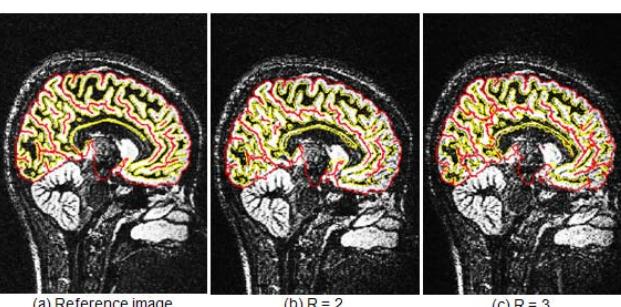
(a) Reference image (b) R = 2 (c) R = 3
Figure 2.
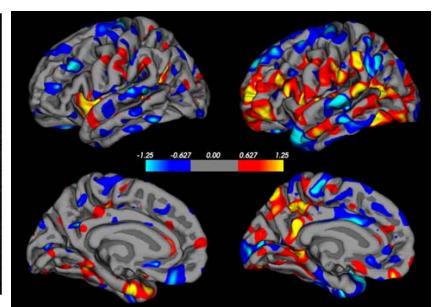
Figure 3.

Figure 1: Shows signal loss due to susceptibility artifacts (white arrow). ((a) MP-RAGE image, (b) DIR image)
Figure 2: Images reconstructed using GRAPPA ((a) Reference image, (b) R=2, (c) R=3)
Figure 3: Average thickness difference between reference and R=2 (left), between reference and R=3 (right)

Discussion and Conclusion

DIR imaging is relatively free from susceptibility artifacts compared to 3D MP-RAGE. But one of the drawbacks of DIR imaging is its long scan time. To shorten the lengthy scan time of 3D DIR imaging, we applied a parallel imaging algorithm to undersampled k-space and determine the cortical thickness changes. From the simulation results, parallel imaging can be done with reduction factors 2 or 3 without large loss in image quality at 3.0T. The results should equally apply to other parallel imaging schemes. In conclusion, using DIR imaging and its advantage of reduced artifacts compared to gradient echo based schemes, cortical volumetric studies can be performed within a clinically acceptable scan time.

References

[1] E. Yoo, et al., ISMRM, 2008.
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