SENSE factors for reliable cortical thickness measurement

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Introduction

With the advent of parallel imaging such as sensitivity encoding (SENSE), fast MR imaging is feasible. This may be beneficial for pediatric neuroimaging for reducing acquisition time. However, parallel imaging has a drawback of decrease in signal-to-noise ratio, which may affect the results of visual analysis, volumetry, and cortical thickness measurement. Cortical thickness as a promising index for brain researches can be measured by using a precise computation without manual drawing due to the innate 3-D folding patterns of the brain (1, 2). According to Han et al (3), cortical thickness measurement can be affected by the scanner manufacturer, scanner field strength, upgrade, pulse sequence, and parameters used in the post processing. The reliability for the effect of SENSE factor has not been evaluated. The purpose of this study was to examine the effect of SENSE factor according the scanner field strength, i.e., 1.5 T and 3.0 T on the cortical thickness measurement.

Methods

Ten healthy volunteers underwent MRI using 3D T1 turbo field echo (TFE) sequence at both 1.5 T and 3.0 T MRI scanners (Intera Achieva, Philips Medical Systems) with different SENSE factors. The SENSE factors compared were 1.0 (without SENSE), 1.5, 2.0, 2.5, 3.0, and 4.0 at both 1.5T and 3.0 T scanners. The images acquired without SENSE at 3.0T scanner was regarded as a reference for all other images since it has the highest SNR among the acquisition in theory. Twelve scans per subject and in total 120 T1-TFE images were acquired. All 3D T1-TFE sequences compared in this study comprised the following acquisition parameters: 182 coronal acquisition with a 224×256 matrix; 220 mm field of view; 0.98×0.98×1.2 mm^3 voxels; TE, 4.6 ms; TR, 9.7 ms; flip angle, 8°; slice gap, 0 mm; 1 averaging per slice. Cortical thickness of the entire brain was automatically calculated using Freesurfer v.3.0.3 (MGH, Harvard, http://surfer.nmr.mgh.harvard.edu), one of most widely used software for cortical thickness measurement. Automated calculation of thickness from all images was performed without any manual intervention at a quad PowerMac which takes about 28 hours per image. In order to compare cortical thickness between scans and between subjects, all cortical thickness measurement were transformed into a template surface space using a surface-based registration scheme. The template surface was generated from the data used in the study. In order to simplify comparison between scans, cortical surface of the template was subdivided into 34 regions (4) and mean thickness at each cortical region was calculated for each scan. The global cortical thickness was compared among the MRI at each scanner with various SENSE factors by using repeated measures one-way ANOVA. Between the scanners, Wilcoxon sign ranks test was performed to test difference of the mean global cortical thickness.

Results

The acquisition time and global mean thickness of the entire cortical gray matter for each protocol was displayed in the Table 1. The maximum SENSE factor without significant difference of the mean global cortical thickness among MRI was 3 at 3.0 T and 2.5 at 1.5 T. All mean global cortical thickness was significantly higher at 3.0 T ($p = 0.005$). Repeated measures of ANOVA of 3.0 T data showed the significant effect ($p<0.001$) of SENSE factors on the mean cortical thickness at visual cortex (p=0.000001), postcentral gyrus (p=0.0006), superior temporal gyrus (p=0.00005) except for lateral orbito-frontal lobe (p=0.00007). In 1.5 T scanner, most cortical regions (22 out of 34 for $p<0.01$ and 18 for $p<0.001$) were significantly affected by the SENSE factor in terms of the measurement of mean cortical thickness.

Discussion and Conclusion

The time required for structural scan was reduced almost inversely proportional to the SENSE factor. The cortical thickness measured at 3.0 T biased to be thicker than that of 1.5 T. The SENSE factors affect cortical thickness measurements highly in the 1.5T while little in the 3.0 T. According to the results, fast imaging can be done with high SENSE factor for example, 2.5 and 3.0 without loss of big image quality at 3.0 T. In this study, the comparison data includes the surface registration with surface smoothing which might cause measurement errors. However, most of neuroimaging area requires the basic procedure done by our experiments and the results of our data explains the reliability of cortical thickness measurement on the practical environment of the research. In the current study, the effect of the SENSE factor on subcortical regions was not tested. By comparing data using voxel-based morphometry, the reliability could also be estimated. In conclusion, high SENSE factor in 3.0 T can be acceptable for the current state-of-the art computational algorithm to estimate reliable cortical thickness.

Table 1. Acquistion time and mean gray matter thickness of entire cortical surface accoring to the SENSE factor and the field strength.

SENSE-Tesla	S1.0-3.0T	S1.5-3.0T	S2.0-3.0T	S2.5-3.0T	S3.0-3.0T	S4.0-3.0T	S1.0-1.5T	S1.5-1.5T	S2.0-1.5T	S2.5-1.5T	S3.0-1.5T	S4.0-1.5T
Time (min:sec)	11:28	8:32	6:23	5:5	4:14	3:14	11:28	8:32	6:23	5:5	4:14	3:14
Thickness*	2.37(.036)	2.39(.056)	2.39(.056)	2.39(.064)	2.39(.066)	2.37(.066)	2.29(.056)	2.31(.056)	2.31(.067)	2.30(.064)	2.29(.051)	2.23(.066)

*Thickness: Mean(SD) in mm unit.

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