Effects of distortion and inhomogeneity correction on brain morphometry with 3T MRI

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Purpose

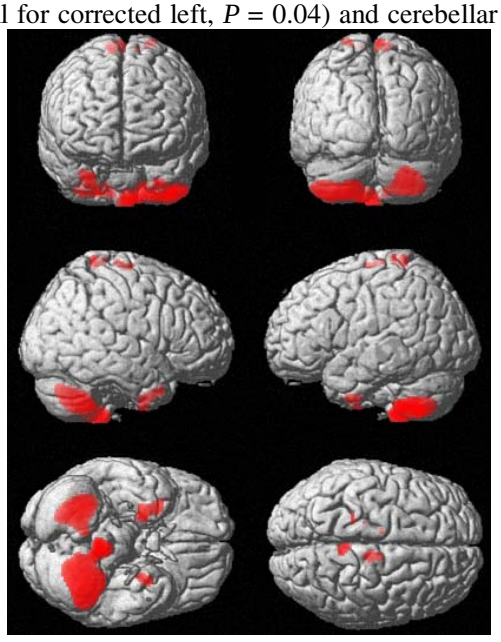
To investigate the effects of distortion and inhomogeneity correction on brain morphometry with 3T MRI.

Materials and Methods

The subjects were 16 normal male volunteer (29.4 ± 4.0, 24-38 years old). MRI data were obtained using a 3T scanner (Signa HDx3.0T, GE Healthcare) at the University of Tokyo Hospital. 3D fast spoiled-gradient recalled acquisition in the steady state (3D-FSPGR) was used to obtain 176 contiguous axial T1-weighted images (TR/TE/TI = 6.8/1.9/450 msec, NEX = 1 and 0.9375×0.9375×1 mm) using 8 channel phased-array head coil without parallel imaging technique. To unwarp distortions from gradient non-linearities, we used Gradient Non-Linearity Distortion Correction (http://www.nbirn.net/tools/gradient_non_linearity/index.shtm), which enables a 3D distortion correction based on knowledge of the spherical harmonic coefficients from the imaging gradients. Then, signal intensity inhomogeneities were corrected using N3 software (http://www.bic.mni.mcgill.ca/software/N3). The 3D-FSPGR images without and with correction were bias-corrected; spatially normalized; segmented into gray matter, white matter, and cerebrospinal fluid images; and intensity-modulated using SPM5 (http://www.fil.ion.ucl.ac.uk/spm). To avoid classification errors, brain volume images were created by adding spatially normalized and intensity-modulated gray and white matter images, and smoothed with 12 mm isotropic Gaussian kernels. Then, brain volume images with correction were subtracted from those without correction, and one-sample t test was performed with age as a confounding covariate. The significance was corrected for multiple comparisons using false discovery rate. Regional brain volumes and cortical thicknesses obtained with FreeSurfer (http://surfer.nmr.mgh.harvard.edu) were tested with a paired *t* test. Moreover, global gray and white matter volumes were compared using two-factor repeated measures analysis of variance to test the interaction between the software used (SPM5 vs FreeSurfer) and the correction. Significance level was set at *P* value of less than 0.05.

Result

In the voxel-based SPM analysis, the significantly larger volumes with corrected images were observed in the brainstem, lower part of the bilateral cerebella, and bilateral fronto-parietal lobes, compared with uncorrected images (Figure). SPM-computed global gray (uncorrected, 683.6±59.2 ml; corrected, 677.2±53.7 ml; $P = 0.07$) and white matter volumes (uncorrected, 468.0±41.2 ml; corrected, 464.9±39.3 ml; $P = 0.23$) without correction were slightly larger than those with correction, but the difference was not significant. In contrast, FreeSurfer-computed volumes of brainstem (uncorrected, 22.0±2.1 ml, corrected, 22.8±2.1 ml, $P < 0.0001$), bilateral cerebral (324.7±25.1 ml for uncorrected right, 329.4±25.4 ml for corrected right, $P < 0.02$; 324.5±23.3 ml for uncorrected left, 328.9±24.4 ml for corrected left, $P = 0.04$) and cerebellar cortices (67.7±6.2 ml for uncorrected right, 69.3±5.7 ml for corrected right, $P = 0.005$; 65.3±6.2 ml for uncorrected left, 66.3±5.5 ml for corrected left, $P = 0.02$) with correction were significantly larger than without correction. Furthermore, FreeSurfer-computed cortical thicknesses of the left entorhinal cortex (uncorrected, 3.60±0.31 mm, corrected, 3.72±0.31 ml, $P = 0.01$), left inferior temporal cortex (uncorrected, 3.28±0.17 mm, corrected, 3.33±0.14 ml, $P = 0.03$), and right middle temporal cortex (uncorrected, 3.32±0.18 ml, corrected, 3.36±0.15 ml, $P = 0.01$) were significantly larger with correction than without correction. Two-factor repeated measures ANOVA revealed that global gray and white matter volumes were significantly affected by the software used but not by the correction, and the software-by-correction interaction was not significant.



Conclusion

This study suggests that the analytical software has the largest effects on brain morphometric measures, and the distortion and inhomogeneity correction have small but significant effects on regional gray matter volumes and cortical thicknesses. Gradient-nonlinearity-induced spatial distortion and signal inhomogeneity correction allow accurate cross-platform or longitudinal comparisons of quantitative morphometry results.