Evaluation of the image intensity non-uniformity correction power in voxel-based morphometry

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[Introduction]

Elucidation of a patient condition and the therapeutic drug development of the Alzheimer's disease are expected by Alzheimer `s Disease Neuroimaging Initiative (ADNI)[1]. This is a large-scale multicenter study, and the MRI is included in imaging biomarkers. Higher image qualities of the same nature must be achieved across sites and platforms over time at each field strength. A study to solve these problems is already reported [2-5]. As a result, certain types of pre- or post-processing were mandatory: intensity non-uniformity correction, image distortion correction, standardization of imaging sequence, etc. To the best of our knowledge, no study has reported the effect of the non-parametric non-uniform intensity normalization (N3) using voxel-based morphometry (VBM) [6] in 3T images and 1.5T images. The aim of the present study is to evaluate the effect of intensity correction on local volume in a voxel-wise manner.

[Materials and Methods]

GE3T protocol: On a 3.0-T scanner (Signa EXCITE HDx, GE Medical Systems, Waukesha, WI, USA), MRI data were obtained with 8-channel brain phased-array coil. Three-dimensional magnetization-prepared rapid gradient echo (MP-RAGE) was used to obtain 170 contiguous sagittal T1-weighted images with a slice thickness of 1.2 mm, repetition time / echo time = 2300 / 2.8 ms, inversion time = 900 ms, flip angle = 8°, field of view = 26 cm, 256×256 pixel matrix. GE1.5T protocol: MRI data were obtained using a 1.5-T scanner (Signa EXCITE HDx, GE Medical Systems, Waukesha, WI). A quadrature head coil was used for send-receive. Three-dimensional MP-RAGE was used to obtain 184 contiguous sagittal T1-weighted images with a slice thickness of 1.2 mm, repetition time / echo time = 3000 / 3.9 ms, inversion time = 1000 ms, flip angle = 8°, field of view = 24 cm, 192×192 pixel matrix. 22 normal volunteers were scanned in both protocols on the same day. We used Statistical Parametric Mapping 5 (SPM5) software for analysis. The MP-RAGE images in native space were bias-corrected, spatially normalized, and segmented into gray matter, white matter, and cerebrospinal fluid images; the voxel sizes of the normalized images were 2 × 2 × 2 mm. The affine regularization space template from the International Consortium for Brain Mapping was changed from the European to the East Asian brain template. Statistical significance for white matter volume between the 1.5-T image group and 3.0-T image group was tested. To test hypotheses with respect to regionally specific group effects, the estimates were compared with two linear contrasts. The significance of each region was estimated by distributional approximations from the theory of random Gaussian fields. A *P* value of less than 0.05 uncorrected in voxel difference was considered to be statistically significant. We compared 1.5T and 3T images after three kinds of intensity non-uniformity correction as follows: extremely heavy regularisation (10) in SPM5, N3 with extremely heavy regularisation (10) in SPM5, and no regularization (0) in SPM5.

[Results]

We showed areas with significantly increased volume in 1.5T images compared with 3T images in Figure. A *P* value of less than 0.05 uncorrected in voxel difference was considered to be statistically significant. Top images are sagittal view, and bottom images are axial view. The areas and max *T* value with significant group difference were the smallest in no regularization (0) in SPM5 (Right, Max *T* value = 1.74, *P* value = 0.041) compared with extremely heavy regularisation (10) in SPM5 (Left, Max *T* value = 5.51, *P* value < 0.0001 and N3 with extremely heavy regularisation (10) in SPM5 (Middle, Max *T* value = 3.53, *P* value < 0.0001).

[Discussions and Conclusion]

Because we compared the same volunteer group, it was supposed to be no significant group difference. However, there are significant group differences. The cause will be due to intensity non-uniformity in the 3T image. If there is no significant group difference, such an intensity correction is believed to be efficient. In the present study, the intensity non-uniformity correction is more effective in SPM5 than N3. It is impossible to measure “real brain volume” and there is no gold standard of brain volume measurement. However, this result suggests that intensity non-uniformity correction is necessary to reduce inhomogeneity between MR scanners. This study was conducted as a part of J-ADNI study.

[Reference]

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