

Multi-site structural MRI studies: an evaluation of image distortions and image intensity reproducibility

J. Jovicich^{1,2}, D. Greve^{1,2}, E. Haley^{1,2}, D. Kennedy^{1,2}, Y. Tosa¹, R. L. Gollub^{1,2}, B. Fischl^{1,2},
A. Dale^{1,2}, B. Morphometry BIRN²

¹MGH/MIT/HMS Athinoula A. Martinos Center for Biomedical Imaging, Charlestown, MA, United States,

²Brain Morphometry BIRN, www.nbirn.net, BIRN, United States

INTRODUCTION

The *Brain Morphometry* Biomedical Informatics Research Network (BIRN, www.nbirn.net) is a group of seven research institutions examining neuroanatomical correlates of neuropsychiatric illnesses. One of the goals of this testbed is to standardize and calibrate structural MRI acquisition protocols to facilitate precise, quantitative evaluation of imaging data using segmentation/morphometry tools from any of the imaging sites, minimizing dependence on site-specific factors. This abstract describes: a) a method for characterizing and correcting site-specific MRI distortions, b) a common structural MRI acquisition protocol for multi-site morphometry studies, and c) an evaluation of image intensity test-retest reproducibility, within-site (important for longitudinal studies), across-site (important for multi-site studies).

MATERIALS AND METHODS

Characterization of MRI distortion and correction: To quantitatively characterize the extent of image distortions due to gradient non-linearities, images of a cylindrical phantom were collected from 4 sites having 2 different commercial 1.5T whole body scanners used for fMRI and structural studies amongst the BIRN sites: General Electric Signa (3 sites) and Siemens Sonata (1 site). The phantom (250mm diameter x 220mm) consisted of plastic plates with 10mm diameter fluid filled spherical depressions spaced on an even 20±0.05mm grid. For the distortion correction, a displacement vector map was calculated using the spherical harmonic coefficients from the vendor's true gradients and then applied to the original image. Measuring the phantom diameter along the z-axis in the corrected images and comparing with the true diameter quantified distortion correction. Standardization of image acquisition protocol: A 3D-spoiled gradient echo (TR=20ms, TE=6ms, 256x192, 1.3mm thick 124 sagittal slabs), with multiple flip angle acquisitions (30, 50, 200 and 300, 8-minute scan per flip angle) was used for acquiring human MRI data for morphometric studies at the participating sites. This standard protocol, easy to implement at all sites, allows the estimation of subjectspecific tissue parameters maps (T1 and proton density). These maps have several potential uses, including characterization of illness [1], as well as improved segmentations for morphometric analysis [2]. Healthy volunteers (5) were scanned twice, in different sessions, at the 4 sites using this acquisition protocol. Each scanning session was summarized in one synthetic 300 scan created from the estimated T1 and proton density parameter maps.

Evaluation of test-retest reproducibility: Reproducibility of image intensity was assessed both by inspecting the relative error maps and by histogram-derived measures (peak and full width half maximum - FWHM) of the relative error distributions in brain voxels (see Figure). Human data was grouped by site, to assess within-site variability, and by subject, to assess across-site variability, with 'raw' and distortion corrected sets for each analysis.

RESULTS AND DISCUSSION

Phantom results show that image distortions due to gradient non-linearities can be significant (~5% mean diameter error), highly variable across sites (2% std), yet can be accurately corrected (0.4% ± 0.2% diameter

error across sites). Human results show that within-site test-retest reproducibility of image intensity is characterized by histogram peaks centered at 0 and mean FWHM of 2.7% for Duke (n=2), 3.3% for MGH (n=4), 2.2% for UCSD (n=5). An ANOVA showed a significant site effect ($p=0.02$). Across-site reproducibility results show that for 5 subjects, each scanned at 3 sites, both the mean histogram FWHM (5.2%) and peak (2.4%) are significantly larger ($p<0.01$) than within-site measures. Distortion correction did not significantly improve (i.e., reduce) the histogram's FWHM or peak for either within- or across-site comparisons.

CONCLUSIONS

Preliminary results show that although distortion correction improves image geometric reproducibility as assessed by phantom data (quantitative evaluation) and human data (qualitative observation), it does not significantly improve histogram-derived reproducibility parameters of image intensity. Additional work is on-going to complete the acquisition and analysis of the within and across site image data, to evaluate the contrast to noise properties of the scans, to evaluate the within and across site variability of the quantitative morphometric results and to further improve the MRI sequence parameters for optimized brain tissue segmentation algorithms.

REFERENCES: [1] Salat et al, HBM 2002; [2] Fischl et al.,HBM 2003

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