Comparison of Registration Technologies for the Evaluation of Diffusion Tensor Imaging

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Introduction Single-shot spin-echo EPI, a most prevalent diffusion-weighted imaging technique, suffers from geometric distortions due to eddy-currents and magnetic susceptibility inhomogeneity. Therefore, the correction of the image distortion is very important to assess micro-structural changes using diffusion tensor image (DTI) within brain *in vivo*. Image registration is often used to reduce eddy current effects. The aim of this study is to investigate the potential advantage of several registrations in the domain of the raw diffusion-weighted images (DWIs) and to evaluate the usefulness of each registrations to correct the distortions in series of DWIs.

Methods The diffusion tensor images of 21 healthy volunteers were acquired from a Philips 1.5T MRI scanner with shielded magnetic field gradients of 30 mT/m and SENSE head coil. The six different directional DWIs were obtained using a single-shot echo-planar acquisition with the following parameters: 220-mm field of view, 128*128 acquisition matrix reconstructed to 256*256 matrix and 4 mm slice thickness without gap, TE 62 ms; TR 7390 ms; b-factor of 600 smm^{-2}; non-cardiac gating; anterior-posterior phase encoding. In order to remove eddy current artifacts, we used AIR [1] and modified SPM-based procedure [2] to coregister DWIs to non-diffusion weighted reference image. We evaluated the performance of three spatial registration schemes: 1) affine registration maximizing mutual information (MI) between DWIs and the reference image, 2) affine registration minimizing the standard deviation (SD) of ratio images between DWIs and the reference image, and 3) 2nd-order nonlinear 30 parameter polynomial transformation model, respectively. The diffusion tensor matrix were generated from a series of DWIs using the conventional multi-linear regression method. Regions of interest (ROI), mainly boundaries between gray matter (GM) and cerebrospinal fluid (CSF), were obtained from intensity-gradient with appropriate threshold in reference image. The variance map of ROI from each DWIs was calculated pixel by pixel. Statistical analysis (one-way ANOVA) was performed to observe the differences of this variance between raw and above three corrected images.

Results The rim along the brain edges in variance maps shows the high intensity differences due to image distortions (Figure 1). Although MI-based affine algorithm, conventionally used in DTI, has better performance compared with the non-correction scheme, image distortion due to nonlinear distortion factor still remains (See arrows.). This situation becomes more serious even in SD based affine algorithm which may not correct the distortion enough. However these effects were not shown in the case of nonlinear strategy. Note that due to the different diffusion properties in the brain tissues, high variances are shown in white matter. Variance of ROI showed statistically significance [$F(3,60)=44.787$, $p<0.0001$] between each registration scheme (Figure 2). Nonlinear registration gave a smaller variances than others (*vs.* non-correction and *vs.* SD-based: $p<.0001$, and *vs.* MI-based: $p=.0418$). MI-based registration was also similar (*vs.* non-correction and *vs.* SD-based: $p<.0001$), and no significant difference was seen between SD-based registration and non-correction ($p=.1664$).

Conclusion & Discussion Instead of sum of squared differences which was insensitive and unsuitable to find the geometric distortion, variance map was used for the effective evaluation measure to detect the mismatch caused by a differential distortion in DWIs. In our study, this variance measure was efficient especially in boundaries between GM and CSF which had the similar signal intensity of anisotropic diffusion in each DWIs. Low variance in this region corresponded to the better alignment for distortion correction of each DWIs. Thus we have evaluated the performance for several registration algorithms in reducing eddy current effects using this measure. In general, MI based affine registrations have been conventionally accepted for registering different-modality images. However, in the case of heavily distorted DWIs by eddy currents, nonlinear registration showed better performance for the correction of the well-known linear distortions and nonlinear factor of distortions, and MI or SD based linear approaches were not appropriate to correct these distortions.

References 1. Woods RP et al. J Comput. Assist. Tomo. 1998; 22: 139-152 2. A Collignon et al. Proc. Inform. Process. Med. Imag. 1995;

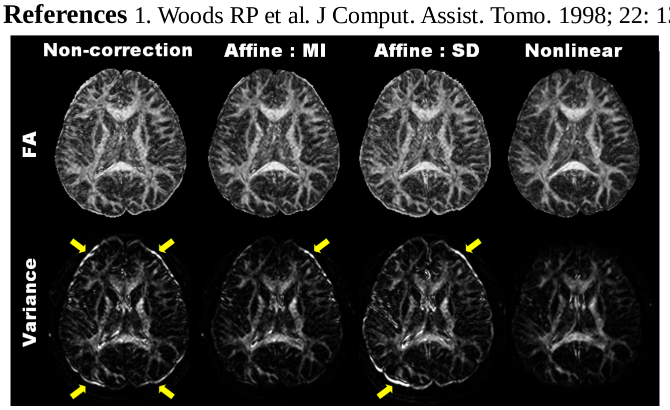

Figure 1. FA and variance map from not-corrected strategy, affine transformation with the minimization of MI, affine transformation with the minimization of standard deviations of ratio images, and 2nd-order nonlinear 30 parameter polynomial transformation model.

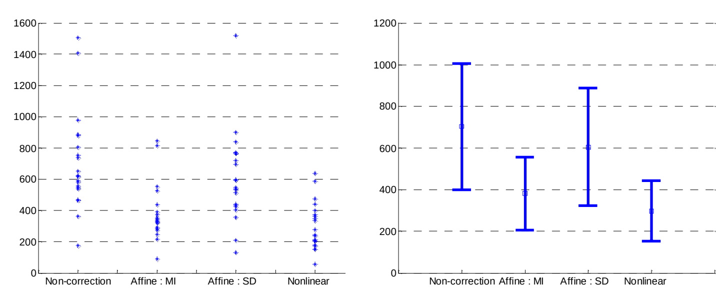

Figure 2. Plot of ROI variances from each strategies (Left) and its mean and variances (Right).