Anatomic versus Fractional Anisotropy Images for Registration of Group DTI Morphometry Data

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Introduction

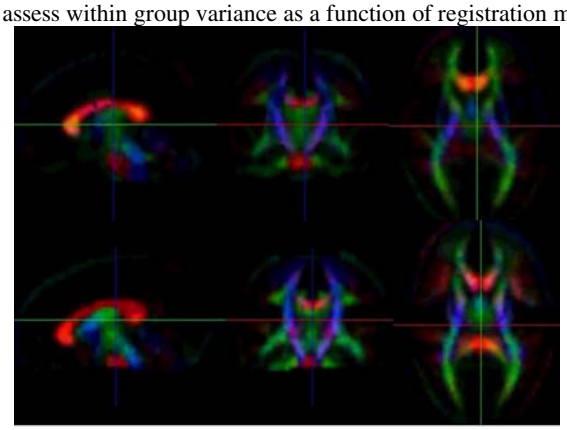
Diffusion tensor imaging is showing promise for investigating differences in white matter structure across different study groups. It is common practice to align diffusion images to their corresponding non-diffusion weighted (T2-weighted) images using a rigid or affine registration procedure. In aligning multiple subjects the tissue of interest is the white matter and thus registration approaches that rely on both gray and white matter T2-weighted contrast and ignore the underlying white matter structures are not making full use of the available data. Thus, different tracts may be mapped onto the same region or onto gray matter, which may bias the results. In addition, an affine registration can neither compensate for the nonlinear deformations seen in the EPI acquisitions, nor allow for the natural variation of the white matter tracts. In this work we compare within group FA variance measures in specific white matter structures following alignment with anatomical T2-weighted images or with direct FA maps using either an affine or nonlinear registration algorithm.

Methods

Three groups of subjects from a reading study, were classified as: 1) Dysfluent and Inaccurate Decoding (DFI; n = 23); 2) Dysfluent and Accurate (DFA; n = 69); and Nonimpaired readers (NI; n = 23) based on a series of behavioral scores. The study was approved by the local IRB and all subjects gave informed signed consent. Diffusion tensor images[3] were diagonalized to yield the eigenvectors and corresponding eigenvalues. Using the tensor eigenvalues, Fractional Anisotropy (FA) maps for each subject were calculated. In order to identify possible differences in FA between the the control and patient groups, an in-house spatial normalization program was employed[1]. A non-linear registration method based on a Tensor B-Spline transformation was employed along with a mutual-information similarity metric. Directional colormaps[2] as shown in Fig.1a below in the nonimpaired control group were then used to manually delineate specific anatomic white matter fiber tracks including the left and right arcuate fasciculus, inferior longitudinal fasciculus, inferior-frontal occipital fasciculus, and superior fronto-occipital fasciculus. Within these ROI's mean FA values and standard errors were calculated for both anatomically based group registrations and for FA based group registrations. A ratio parameter StErr/meanFA was defined to assess within group variance as a function of registration method.

Results and Discussion

The directional color maps were clearer in the FA registered group relative to the anatomically registered group – sample shown in Fig.1a above. The quantitative data reveal that in each ROI the Standard Error to mean FA ratio decreased when FA registration was used compared to anatomic registration, by up to 50% in some cases (left arcuate, DFA group). This finding was consistent across ROI's and within each subject group.



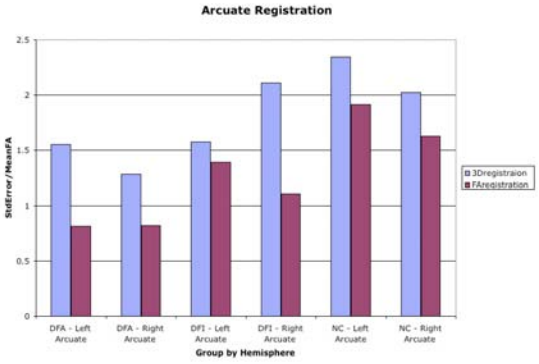


Fig. 1a) Group diffusion tensor color imaging maps showing underlying white matter structures on which the ROIs were defined. Top row registered using anatomic information, bottom row registered using FA maps. The bottom row shows sharper delineation of white matter structures. b) ROI results for the left and right arcuate fasciculus in the 3 study groups demonstrating decreases in the ratio StErr/meanFA within each ROI for anatomic registration (blue) and FA registration (magenta).

This approach is ideal for examining changes in mean FA but changes in the size of different tracts will be eliminated by the nonlinear registration. This information however, is available by examining the transformation matrices needed to transform the FA data into the reference FA space. Contractions or dilations for specific structures indicate a difference in size of these tracts relative to the reference FA map. In summary, our results demonstrate that by using a nonlinear registration method combined with the WM specificity provided by the FA maps allows for a more accurate measurement of differences across groups. Further studies are needed to determine the optimal parameters of the registration to maximize group discrimination.

References

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