Comparison of DTI group analysis using non-linear and linear registration techniques

Blessy Mathew[1], Wanyong Shin[1], Mingyi Li[1], Mark J. Lowe[1], Sarah Banks[2], Michael Phillips[1], Michael T. Modic[1], and Charles Bernick[2]
[1]Cleveland Clinic, Cleveland, OH, United States, [2]Cleveland Clinic, Las Vegas, Nevada, United States

Target Audience: TBI researchers, MRI physicists

Purpose

We have developed the Professional Fighters' Brain Health Study (PFBHS), which is a longitudinal study to investigate brain MRI in a cohort of active professional fighters. From the initial data, region of interest (ROI) based diffusion tensor imaging (DTI) results have been published which shows that fight history or number of times a boxer was knocked out (NKO) predicts DTI changes in 74 of boxers and 81 mixed martial arts fighters(MMA) [1]. Recently, we re-ran DTI group level analysis with the same data using voxel-wise analysis and identical statistical model, not only to replicate the previous finding from ROI analysis, but also to expand from predefined ROIs to the whole brain. In the process, it was discovered that conventional linear registration led to many false-positives near the boundaries of anatomical structures. While it is known that non-linear registration (nLR) of DTI accounts for individual anatomical complexity, leading to better anatomical image alignment, it has not been demonstrated what impact nLR has on group analyses. In this study, we conducted a voxel wise DTI group analysis using linear and non-linear co registration methods, and compared the group analysis results of each of these methods.

Method

Seventy-one professional boxers (mean age=28 ±5 yrs, weight (kgs) =75±15) were scanned on a 3T Verio scanner with a 32 channel head coil. Scans included T1 weighted (T1w) scan, and 71 directional diffusion weighted DTI data. From DTI set, individual study's longitudinal diffusivity (LD), transverse diffusivity (TD), fractional anisotropy (FA), and mean diffusivity (MD) maps were calculated. The detailed scan parameters and DTI analysis procedure can be found in ref [1]. For the nLR, a typical brain was selected as a template from the boxer data. Individual T1w image were registered to this template using symmetric image normalization in Advanced Normalization Tools (ANTS) [2]. Registration accuracy was assured by the matching scores developed in our group. Then individual DTI maps were registered to the template using the ANTS transformation matrix determined from the T1w registration. For the Linear Registration (LR), individual T1w volume was registered to Talairach (TLRC) coordinate space, and DTI maps registered to TLRC space using AFNI [3]. A 4mm FWHM spatial filter was then applied to resulting DTI maps from both nLR, and LR techniques. Voxel-wise multiple hierarchical linear regression model was used to test whether NKO could predict DTI measures derived from nLR and LR techniques [1]. Age, weight, and years of education were controlled for in the model to ensure that they would not contribute to the observed effects.

Comparison of nonlinear & linear registered group analysis

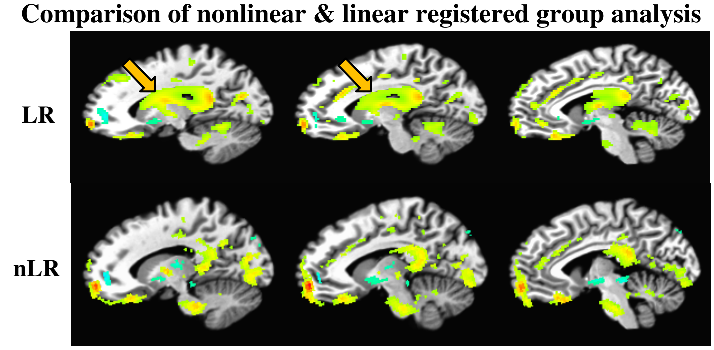

Fig 1. Voxelwise Group analysis result using linear registration (top row) and non-linear registration (bottom row) ($p < 0.05$). For demonstration purpose, non-linear registered result is overlaid on TLRC space.

Results and Discussion

While both nLR and LR results replicate the previous finding that NKO predicted increasing TD ($p<0.01$) in posterior corpus callosum, hippocampus, amygdala, lingual gyrus, cuneus, and inferior parietal [1], LR results presented potential false positive in ventricle areas, as shown by arrows in Fig 1.

Conclusion

We demonstrated that DTI group analysis using LR technique generates the possible false positive finding mainly due to the imperfect alignment, especially near corpus callosum and ventricle areas, and nLR DTI group analysis improves registration performance, leading to the minimized potential bias source and improved the statistical power. We conclude that, in a large cohort of subjects at risk for brain trauma, the nLR technique is better at detecting group-level structural changes than the LR technique

References

[1] W.Shin et al, AJNR, 2014(35);285-90, [2] Avants BB et al, Med Image Anal, 12 (1), 26-41, [3] Cox et al, 1997(10):171-178