Effects of Gender and Handedness on Corticospinal Tracts: Tract Specific Analysis of Fractional Anisotropy Based on Diffusion Spectrum Imaging

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Abstract

This study examined the asymmetry of bilateral corticospinal tracts (CST) using diffusion spectrum imaging tractography. The variations of CST at the microstructural level, as reflected by fractional anisotropy, suggested that there was leftward asymmetry in CST for right-handers, specifically for right handed females.

Introduction

Experimental studies of asymmetric variation in human cerebral hemispheres have suggested that there is a functional and morphological laterality [1]. For instance, differences in brain laterality between males and females affect language processing and other aspects of cognition [2; 3]. Moreover, fMRI studies showed that left-handers and right-handers differed in their patterns of brain activation and motor area extent when performing sequential finger movements [4]. Albeit it has long been thought that the laterality of functional areas is related to gender difference and handedness, experimental evidence regarding to asymmetry of anatomical microstructure is rare and inconsistent. Therefore, the main purpose of this study is to characterize and to compare the motor neural circuit associated with dominant and non-dominant hands in males and females using diffusion spectrum imaging (DSI) tractography. Hand manipulation is controlled by the contralateral cerebral motor cortex through the corticospinal tract (CST). Given its functional relevance to fine motor manipulation, we assumed that variations of CST at the microstructural level, as reflected by the measured fractional anisotropy (FA), might be correlated to handedness and gender.

Materials and Methods

Subjects Twenty-five adults were recruited in the study (11 males and 14 females; age range: 17-28 years; mean: 22.96 ± 4.7 years). Fifteen were consistent right-handers and ten were consistent left-handers. All subjects received the Edinburgh Handedness Inventory before the study. They were selected if they had the scores either larger than +40 (right preference) or less than -40 (left preference). *Diffusion Spectrum Imaging* All images were acquired on a 3T MRI system (Trio, Siemens, Erlangen, Germany). DSI experiment was performed with a pulsed-gradient spin-echo diffusion EPI sequence by applying 203 diffusion gradient vectors, each corresponding to one of the isotropic 3D grid points in the q-space, the maximum diffusion sensitivity b_{max}=6000 s/mm^2, TR/TE=9100/142 ms, and isotropic resolution=2.7 mm. Forty-five trans-axial slices were acquired encompassing the whole brain. The experiment completed in 30 min. DSI analysis was based on the relationship that the echo signal S(**q**) and the diffusion probability density function P(**r**) were a Fourier pair [5]. The orientation distribution function (ODF) was determined by computing the second moment of P(**r**) along each radial direction. The main orientation of diffusion probability was then determined by the local maximum vectors of ODF [5;6]. A decomposition method was used to decompose the original ODF into several constituent ODFs, representing the orientations of individual crossing fibers. The shape of individual ODFs allowed us to estimate the fractional anisotropy (FA) of individual fibers as defined by the tensor model. *CST Tractography* Tractography was based on a simple algorithm that was adapted for DSI data. All fiber orientations of the nearest voxels were used to decide the proceeding orientation for the next step; the most coincident orientation less than 45° was chosen. A new starting point was then obtained to repeat the same tracking procedure. Tracking stopped if there was no coincident orientation in the nearest voxels [7]. The algorithm started with placing the seed points in the cerebral peduncles, and the tracts that passed through the pyramid and motor cortex were selected (Fig. 1). Having obtained CST, FA of the decomposed ODFs along CST specifically arising from the internal capsule to hand motor cortex was analyzed. *Statistic Analysis* Subjects were divided into four subgroups, namely, female right-handers (N=9), female left-handers (N=5), male right-handers (N=6) and male left-handers (N=5). Data analysis included the computation of descriptive statistics. In each subgroup, paired t test (two tailed) was used to compare FA in the left CST versus that in the right CST. The difference was considered significant if P<0.05. Further, a linear regression technique was used to compare the qualitative difference of FA between left CST and right CST on handedness and gender. Predictor variables with P<0.05 were entered into a multivariable regression analysis using the "Enter" method. The predictor variables included sex (male=0, female=1), handedness (left=0, right=1).

Results

There was a tendency of increased FA toward the left CST in the right-handers. In the right-handed females, FA in the left CST was significantly higher than that in the right CST (p=0.006), but the difference was insignificant in the right-handed males (p=0.507). In the left-handers, FA between bilateral CSTs did not show any significant difference (Fig. 2). When two parameters (gender and handedness) were entered into the multiple regression model, FA difference between left and right CST was associated with gender and handedness (p=0.044, R-square=0.249).

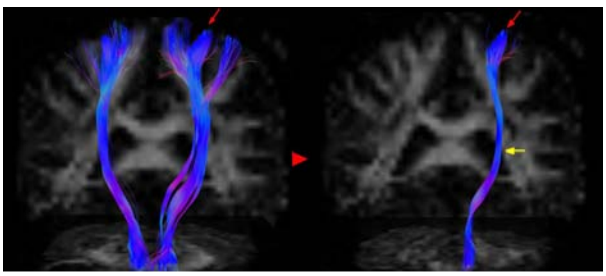

Figure 1. Tractography of bilateral CSTs. The red arrow points out part of the CST arising from motor area of hand. The yellow arrow indicates internal capsule where CST starts to spread out and go to different functional regions. In this study, we focused on the CST from internal capsule to motor cortex which controls hand movement.

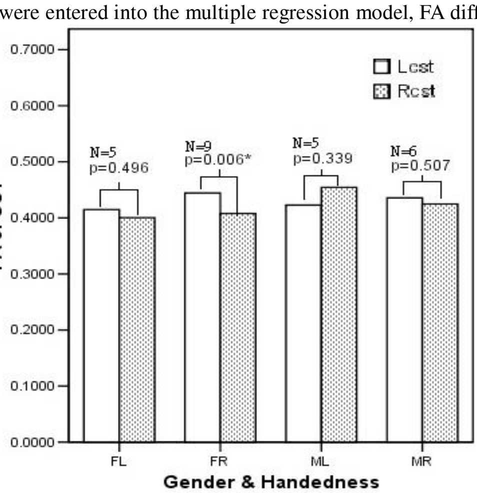

Figure 2. Fractional anisotropy to female left-handers (FL), female right-handers (FR), male left-handers (ML), and male right-handers (MR). The difference between FA of left CST and that of right CST was significant in right-handed females.

Conclusions

We have quantified diffusion property along CST using tract specific analysis.Using FA as an index to indicate the degree of axonal myelination, we have demonstrated leftward asymmetry in CST for right-handers, specifically for right-handed females.

References

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