Age Effect on Development of Eighteen Segmented Callosal Fibers: A study using a diffusion spectrum imaging template and tract-based statistical analysis

Hui-Hsin Hu[1], Yung-Chin Hsu[1], Yu-Jen Chen[1], Yu-Chun Lo[1], Susan Shur-Fen Gau[2], and Wen-Yih Isaac Tseng[1]

[1]*Center for Optoelectronic Medicine, National Taiwan University College of Medicine, Taipei, Taiwan,* [2]*Department of Psychiatry, National Taiwan University Hospital, Taipei, Taiwan*

Purpose

This study aimed to investigate the pathway-specific development of corpus callosum (CC) during childhood through early adulthood. Interhemispheric connectivity of CC has shown its increasing importance in neuroimage research. Based on the longitudinal diffusion tensor images with increasing age [1], the normal callosal fibers continue to develop from childhood to adulthood and may achieve their peak of averaged fractional anisotropy (FA) value during early adulthood. Such interhemispheric connectivity may be related to the behavioral outcome of preterm babies and the developmental language disorder [2]. A recent study of diffusion-weighted images reported that for adolescent born preterm, the volume of the callosal fibers which connect temporal lobes may predict the impairment of language proficiency [3]. These previous studies showed that the normal development of callosal fibers may provide a valuable baseline in the assessment of the brains with neuro-disorders. However, a few brain regions (about 4 to 5 brain areas) failed to show their callosal trajectories in past diffusion image studies due to the technical limitation of crossing fibers. To address this problem, we used a template of diffusion spectrum image (DSI) to reconstruct 18 callosal fibers (Fig. 1)[4]. The age effect along 18 callosal fibers was separately conducted using the tract-based statistical analysis [5]. The delicate parcellation of CC may provide us with a better understanding of the interhemispheric connectivity.

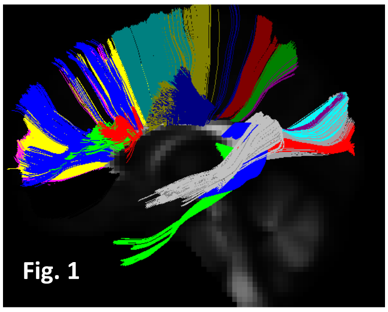


Fig. 1

Methods

This study recruited DSI data of 105 subjects aged from 8 to 25 years old. To obtain the 18 callosal fibers of each subject, the following steps were employed. First, a group template was first established by registering the DSI of all subjects together. Second, the group template was registered to the DSI template in which the 18 callosal fibers have been segmented. Third, the coordinates of the 18 callosal fibers were transformed from DSI template to individual DSI using the transformation matrix between DSI template and group template as well as the matrix between group template and individual DSI. Once we obtained the callosal fibers on individual DSI, mean path length was calculated to gain a mean number of steps along each callosal fiber. As shown in Fig. 2, the CC frontal sup orb (see below) has 118 steps along its path from right to left hemisphere. Finally, the generalized FA (gFA) values of a given step over all subjects showed their age effect using the tract-based statistical analysis [5]. The p value was 0.0028 for the correction of multiple comparisons. Figure 3 exhibits the log 10 of p value (y-axis) for each step (x-axis) along fiber orientation. The vertical dashed line (Fig. 3) was the location of midsagittal plane and divided steps into right and left hemisphere. The step with the value above the horizontal dashed line (Fig. 3) reached the statistically difference of age effect. The 18 callosal fibers were the interhemispheric tracts that connected to frontal superior orbital area (CC frontal sup orb), frontal inferior operculum area (CC frontal sup oper), frontal inferior triangulum (CC frontal inf tri), frontal middle area (CC frontal mid), frontal superior area (CC frontal sup), frontal superior medial area (CC frontal sup med), precentral area (CC precentral), supplementary motor area (CC supple motor), postcentral area (CC postcentral), parietal inferior area (CC parietal inf), parietal superior area (CC parietal sup), precuneus (CC precineus), temporal middle area (CC temporal mid), temporal superior area (CC temporal sup), temporal pole (CC temporal pole), occipital middle area (CC occipital mid), occipital superior area (CC occipital sup), cuneus (CC cuneus).

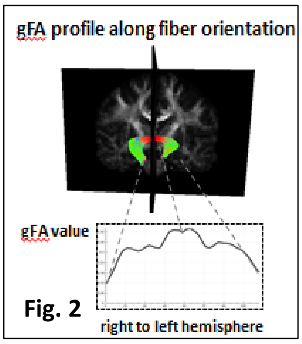
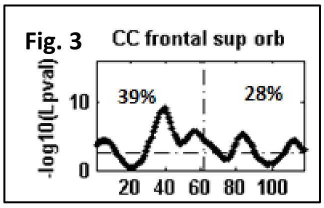


Fig. 2

Results

The proportion of steps with p<0.0028 was computed. Among 18 callosal fibers, the CC frontal sup orb showed highest proportion (67%). That is, the 67% of CC frontal sup orb altering with age from 8 to 25 years old. The second highest one was CC supple motor (61%), followed by the CC postcentral (59%). The proportion of step is separately calculated in two hemispheres (Fig.3) for each callosal fiber. To identify how statistically different the two proportions between hemispheres are, we performed the Chi-square test (statistical toolbox 7.2 in Matlab) on the two proportions for each callosal fiber. We found that the left hemisphere showed a larger proportion than the right hemisphere in CC frontal inf (16% in left hemisphere and 0% in right hemisphere), CC frontal inf tri (19% in left hemisphere and 3% right hemisphere, proportional difference reached p=0.0003) and CC frontal mid (16% in left hemisphere and 0.7% right hemisphere, proportional difference reached p=0.0001). The other callosal fibers presented no proportional difference with p value > 0.05. Based on our results, the age-related changes exhibited the left lateralization in these 3 callosal pathways.

Fig. 3



Conclusions

Our results indicate that callosal fibers connecting to language brain regions, such as inferior frontal area and inferior frontal triangulum, show a left lateralization of age effect. This suggests that the interhemispheric connectivity may correlate with language lateralization during childhood through early adulthood.

References

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