Do Differences in the Left-Right Fractional Anisotropy in the Language Tracts of Right Handed Individuals Correlate with Laterality of Functional Activation?

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Introduction

It is a well known fact that the left and right brain hemispheres of healthy individuals are different. Laterality and handedness are common terms to indicate these differences. The dominance of a particular hemisphere has been generally associated with morphological asymmetry in the cortical grey matter [1] and white matter (WM) connectivity [2]. Tools like fMRI have been successfully used to evaluate hemispherical dominance associated with language and also changes in this dominance with disease. Previously we had presented results for a functional MRI verb generation task [3]. Apart from observing dominant hemisphere language activation, we also observed differential patterns of activations of the language related areas in the non-dominant hemisphere. One study showed evidence of WM asymmetry of the arcuate fascicle (a WM connection between Brocas and the Wernicke's area) and WM related handedness differences using a voxel based approach [2]. The motivation of this study was to segment WM pathways associated with the cortical area (BA44-45) related with language function, study hemispherical differences for these pathways and their subparts, and test if the differences in left-right WM asymmetry are associated with left-right functional differences for a group of healthy individuals with the same dominant hemisphere.

Methods

Nine healthy participants (4 females; mean age, 31; range, 19-64), right handed and native English speakers participated in the study. Diffusion tensor images and 3D inversion-prepared SPGR images were collected from these participants on a Philips Achieva 3T scanner using a SENSE head coil. An echo planar imaging, spin echo, diffusion weighted sequence was used for the diffusion tensor images. Fifteen encoding direction were used with diffusion weighting of 800 s/mm^2 and a non-diffusion weighted reference image. Other imaging parameters were: TE/TR=58/2720ms; matrix=112*112; FOV=22cm, 30 contiguous axial slices with ST=4mm, SENSE=2.4, 3 averages and total acquisition time=2:18s.

The imaging parameters for the 3D SPGR were: TE/TR=4.6/9.9ms; Flip Angle=8°; matrix=256*256; FOV=25cm; 150 sagittal slices with ST=1mm.

The Multi Planar Reconstruction (MPR) was used to reslice the anatomical images in the same orientation of the diffusion tensor images (axial). In addition, all participants performed a simple verb generation task inside the scanner. The details of the task, the imaging parameters and the results can be found in our earlier abstract presented at the 2006 Annual ISMRM meeting [3]. The slice thickness and orientation were the same for the diffusion tensor images and functional images.

Image Analyses: Diffusion weighted images were corrected for eddy current induced image distortions using a 3D affine registration algorithm from the Automated Image Registration (AIR) package. Slices with considerable distortion were excluded from the analyses. Distortion was mainly observed in the slices below the orbitals. White matter tractography was performed using DTIstudio [4]. Fiber tracking was done for voxels with FA>0.3 and was terminated at voxels with FA<0.15 or when the turning angle was greater than 45°.

White matter (WM) pathways that originate or terminate in the BA44-45 area for each individual were obtained using the Brodmann Area template provided with MRIcro software as in [5]. We first registered the individual subject MPR anatomical images to their non-diffusion reference images. Next we registered the 152 brain standard MNI template provided in MRIcro with the individual anatomical images. The cortical areas were weighted in this registration using a binary mask of the complete Brodmann Area template to obtain a better cortical registration. Once the Brodmann template was in the same space as the diffusion images, a binary mask of the BA44-45 area was used to obtain the WM pathways originating or terminating from this area. The individual FA images and the binary mask of these WM pathways were transformed into standard MNI space. Next a probability map of the WM pathways for the BA44-45 area was created by averaging the binary masks for each individual's WM pathway. The probability threshold used was 1 out of 9 subjects i.e. voxels which have no overlap of fibers for even two individuals were considered as part of low probability fibers and excluded (Figure 1). We then divided this high probability WM pathway into 18 parts along the length of the pathway for both the left and right hemispheres (Figure 2). Registration of all images was done using FSL software. White matter for each individual was segmented using the segmentation algorithm provided with SPM2 package.

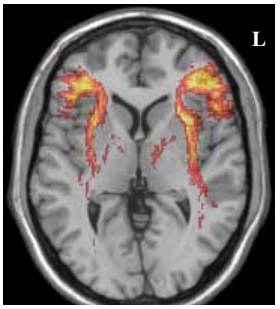
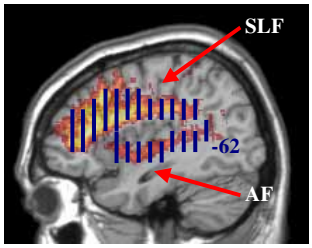


Figure1: Probability Threshold Map of WM pathways (BA44-45)

Figure2: Division of the WM pathway into 18 parts



Statistical Analyses:

Left and right hemisphere nonparametric comparisons of mean FA were done for 1.whole brain WM; 2.WM from axial slices covering the language areas; 3. WM pathway for each individual using the high probability WM pathway mask; 4.WM from the axial slices covering the language areas and not part of the WM pathway mask; and 5.eighteen parts of the WM probability pathway. Functional activation for the verb generation task was quantified by calculating the number of pixels in the left and right BA44-45 area. Laterality index (L – R)/(L + R), for the functional activation was correlated with the FA difference between the left and right hemisphere of the AF tract.

Results

Two pathways traveling anterior-posterior were highlighted in the probability WM map: the arcuate fascicle (AF) and the superior longitudinal fascicle (SLF) (see Figure 2). Differences between mean FA (left>right) were observed in all brain WM (z=2.666;p=0.008), WM from axial slices covering the language areas (z=2.666;p=0.008), AF part of the high probability WM pathway (z=2.073,p=0.038), WM not part of the WM pathway (z=2.666;p=0.008), and parts of the AF – coronal -62 to -52 (vicinity of Wernicke's area, z=2.192;p=0.028), coronal -12 to -2 (vicinity of Broca's area, z=2.666;p=0.008) & coronal -2 to 8 (z=2.073,p=0.038). No significance statistical differences for the SLF or parts of the SLF were seen between the left and right. No statistical significance was observed for the fMRI laterality index and the FA difference for the AF pathway.

Discussion

We were able to map two pathways originating or terminating in the BA44-45 area for our subjects. A characteristic laterality in WM is observed over the entire brain, slices covering certain functional areas and part of the WM not occupied by the WM pathway. The same laterality was also observed for the AF pathway, but no laterality was observed in the FA of the SLF pathway. Studying different parts of a particular pathway or FA changes along the pathway may give useful information. Although group differences between left and right were positive and significant for the entire tract as well as certain parts of the pathway, certain individuals were observed with increased right laterality along the pathway, indicating individual variability in laterality along the pathway. This individual variability may be one of the reasons for the lack of a significant relationship with functional laterality. Another reason may be the low sample size. The results seem to indicate that a careful evaluation of WM pathways is necessary before associating them with a particular function.

References

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