Topography of the Corpus Callosum – A Comparative DTI Study of Human and Rhesus Monkey

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Introduction

In placental mammals, the corpus callosum (CC) serves as the major connection between the two brain hemispheres. In the rhesus monkey this largest cerebral commissure contains more than 56 million fibers interconnecting the frontal, parietal, temporal, and occipital cortices [1]. Similar to humans [2], also the monkey CC is topographically organized. Electron microscopic analyses revealed a segregated distribution of different types of callosal axons, indicating functional differences between commissural connections [1]. A recent re-evaluation of the human CC with use of MRI-based fiber tractography developed a new classification of vertical CC partitions in which the callosal frontal fibers occupy more space than previously assumed [3]. In the past, superior cognitive capabilities of humans relative to non-human primates were mainly attributed to a disproportionate enlargement of the frontal lobe during evolution. Because of the close relationship between the human and monkey brain [4], we applied diffusion tensor imaging (DTI) and region-to-region tract tracing techniques (i) to assess the cortical connectivity pattern of the CC in individual primates, and (ii) to perform a comparative topographic analysis, in particular for transcallosal fibers connecting frontal cortical areas.

Material and Methods

MRI studies of healthy rhesus monkey (n=4) were conducted at 2.9 T (Siemens Trio, Erlangen, Germany) using a small phased-array coil (4 elements) originally designed for human shoulder studies. DTI (36 slices) was based on b values of 0 and 1000 s/mm^2 using 24 independent gradient orientations. Acquisitions were performed at 1.5x1.5x1.5 mm^3 isotropic resolution using diffusion-weighted single-shot stimulated echo acquisition mode (STEAM) MRI sequences and 5/8 partial Fourier encoding in combination with a projection onto convex subjects (POCS) reconstruction algorithm [5]. The acquisition time was 7 min, but analyses were based on 3-4 averages.

Results

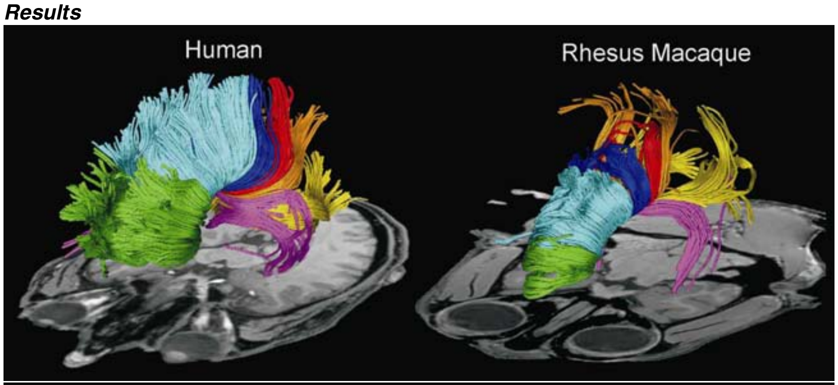

Fig.1 Transcallosal fiber tracts from a single human and macaque subject overlaid onto individual anatomical reference images (scaled to same size). Oblique views of a 3D reconstruction of all callosal fibers comprising bundles projecting into the prefrontal lobe (coded in green), premotor and supplementary motor areas (light blue), primary motor cortex (dark blue), primary sensory cortex (red), parietal lobe (orange), occipital lobe (yellow), and temporal lobe (violet).

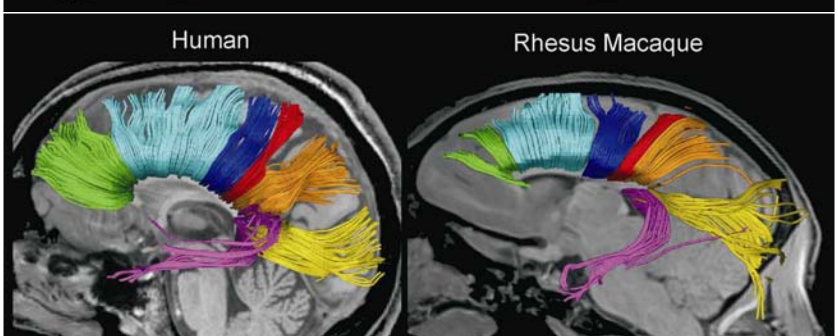

Fig.2 Transcallosal fiber tracts from a single human and macaque subject overlaid onto individual anatomical reference images. Sagittal views of a 3D reconstruction. Color code as above.

Fig.3 DTI-based fiber tractography distinguished 5 vertical partitions of the CC, containing fibers projecting into (I) prefrontal, (II) premotor, (III) motor, (IV) sensory and (V) parietal temporal and occipital cortical areas. A anterior, P posterior

Conclusion

As shown in the Fig.3, DTI-based fiber tractography distinguished 5 vertical partitions of the CC in both human and rhesus macaque brain. In general, the topographic arrangement of transcallosal fiber tracts of either species turns out to be very similar. The relatively large representation of frontal fibers (Fig.3 I–III) is conserved in both the monkey and human brain. Therefore, we underline the view that the *relative* volume of the frontal lobe in hominids did not significantly increase during evolution after the split of the hominid line from other primates. The special cognitive abilities of the human species may rather be due to differences or selective enlargement in special cortical areas and their various interconnectivities.

References

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