An Atlas of Brainstem Connectomes from HCP Data

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Introduction:

The brainstem contains many critical structures but is a challenging area to study with neuroimaging (Alberto: 12). It holds the reticular activating system and is the primary relay center for efferent and afferent connections between the cerebral cortex, spinal cord, and cerebellum (Nolte: 2008). Fiber pathways in the brainstem are critically important for sensory and motor functions, and connect nuclei implicated in the pathogenesis of a wide spectrum of neurological disorders (Manisha :13). Although studies using two-dimensional histological sections and staining methods have been performed to investigate the anatomy of the brainstem (Haines:12), the orientation and three-dimensional anatomical locations of individual tracts, and their spatial positions relative to adjacent pathways are difficult to comprehend. The development of modern imaging techniques and fiber tracking methods facilitate the exploration of the three-dimensional imaging and detailed delineation of the brainstem tracts in vivo (Antonio:16). Using cutting-edge imaging data from the Human Connectome Project (HCP), we propose a novel protocol to generate a total of 29 major tracts in the brainstem and construct a comprehensive population-based probabilistic atlas of brainstem connectivity. Our results will be helpful for the understanding of neuroanatomy of the brainstem, and the pathogenesis of neurological disorders.

Methods:

High quality diffusion imaging data of twenty subjects with minimal susceptibility distortion were selected from the HCP (Van Essen: 12). We reconstructed the brainstem tracts and built a probabilistic tractographic atlas of the brainstem connections. Firstly, the fiber orientation distributions (FODs) were computed using our novel algorithm for analyzing multi-shell HCP data (Tran: 15). Secondly, tract labels were drawn by two experienced neuroscientists, T1- and T2-weighted MR images as well as histological sections were used to assist the labels of region of interest (ROI) and interpretations of tract locations and trajectories. FOD-based probabilistic tractography was then performed to reconstruct the brainstem tracts after positioning the ROI in agreement with the known course of each tract. The tract density image (TDI) (Calamante: 10) of all tracts were warped to the standard MNI152 space using the ANTS software for atlas construction. For each bundle, the warped TDI was normalized and averaged across the 20 subjects to calculate its probabilistic atlas in the MNI152 space.

Results:

For each subject, we reconstructed 29 bundles of the major brainstem pathways. They can be schematically divided into three groups: 1. The major motor tracts running principally on the ventral surface of the brainstem(Fig.1a), including the corticospinal tract (CST), the frontopontine tract (FPT) and the parietooccipitotemporo-pontine tract (POTPT). 2. The cerebellar peduncle(Fig.1b), including the superior cerebellar peduncle(SCP) which was mainly composed of the anterior spinocerebellar tract (SCPSCT), the cerebellorubral tract (SCPCRT) and the cerebellothalamic tract (SCPCRTT and SCPCTT), the middle cerebellar peduncle(MCP) and the inferior cerebellar peduncle (ICP), which was mainly composed of the posterior spinocerebellar tract (ICPSCT), the olivocerebellar tract (ICPOCT) and the vestibulocerebellar tract (ICPVCT). 3. The major sensor tracts(Fig.1c), including the medial lemniscus (ML), the trigeminothalamic tract (TTT), the spinothalamic tract (STT), and the lateral lemniscus (LL). The probabilistic atlas from a subset of reconstructed brainstem bundles were overlaid on the MNI152 space and plotted in Fig.2.

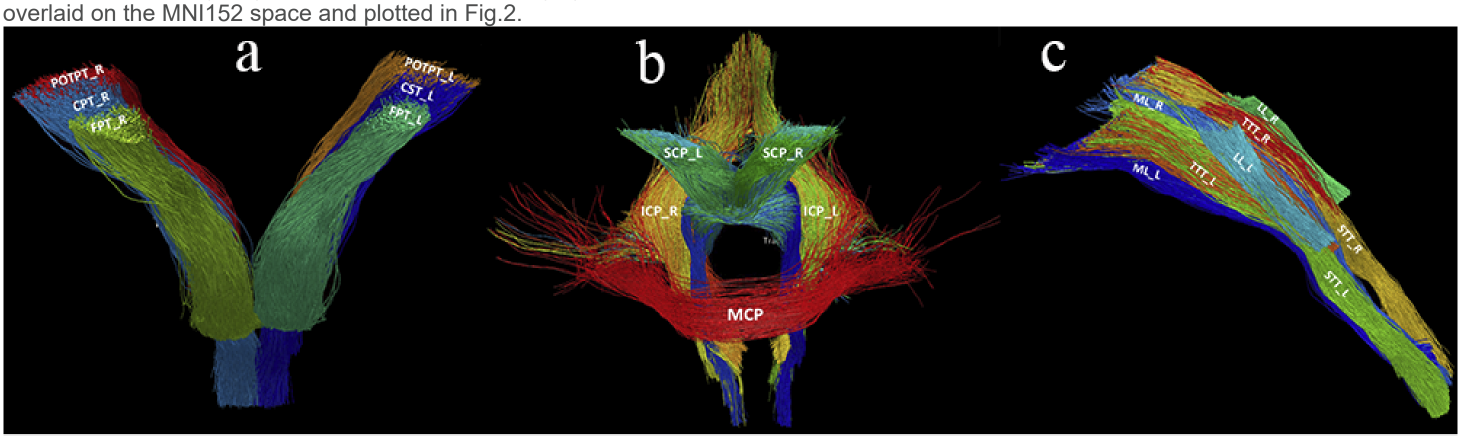

Figure 1. Brainstem bundles generated in our study. (a) The major motor tracts including CST,FPT and POTPT. (b) The anterior view of the three cerebellar peduncles: SCP, MCP and ICP. (C) The lateral view of major sensory tracts including ML, TTT, STT and LL.

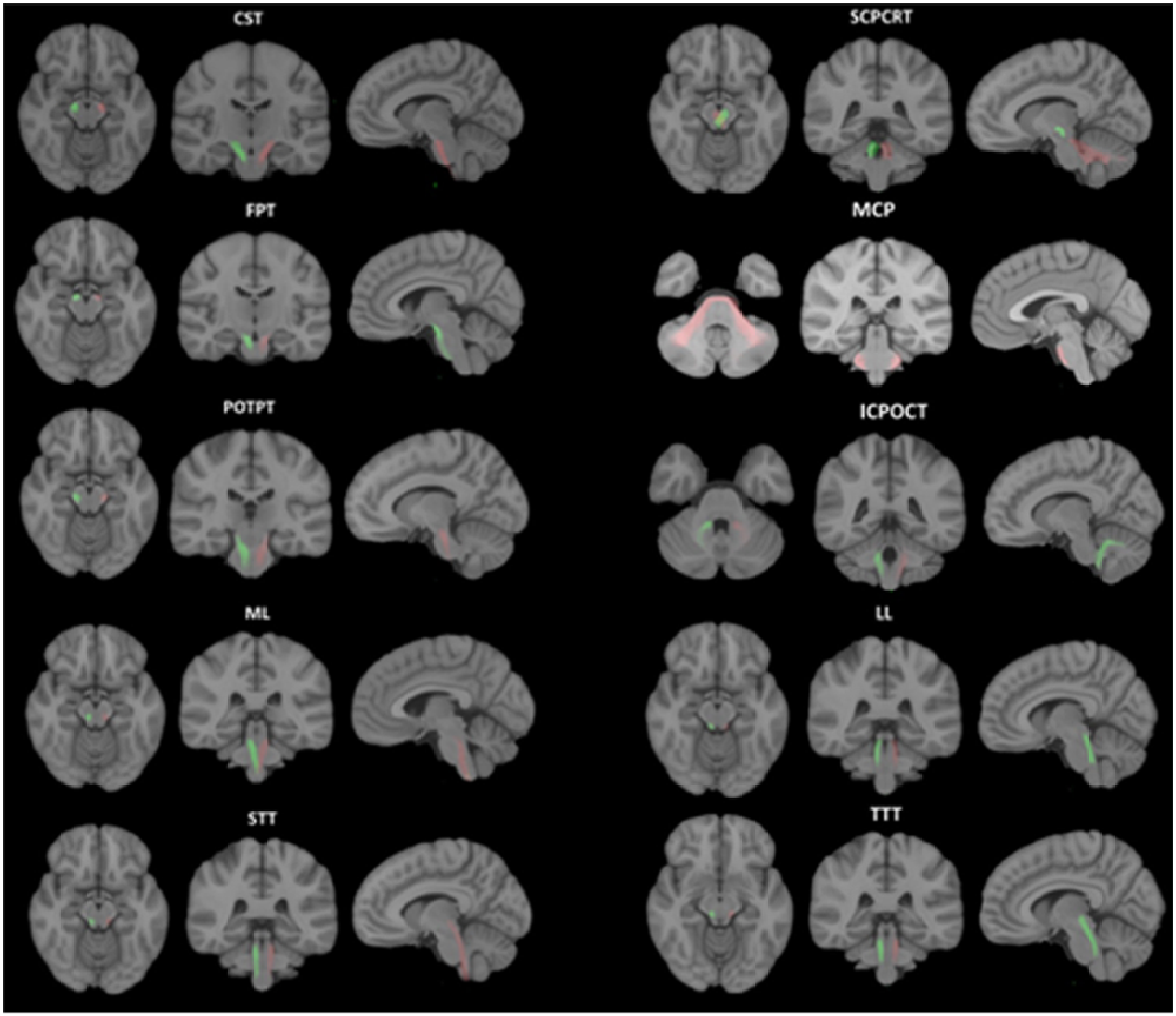

Figure 2. The probabilistic atlases of some selected tracts are shown in the standard MNI coordinate space. For all the tracts except MCP, left tracts are shown in red and right ones are shown in green.

Conclusions:

The tractography and definition of these tracts are helpful not only for exploring the neuroanatomy of the brainstem from imaging data, but can also contribute to the understanding of the pathogenesis of neurological disorders and for planning neurosurgical approaches.

Informatics:

Brain Atlases [1]

Neuroanatomy:

White Matter Anatomy, Fiber Pathways and Connectivity [2]

Poster Session:

Poster Session - Tuesday

Keywords:

Brainstem
Tractography
White Matter
WHITE MATTER IMAGING - DTI, HARDI, DSI, ETC

[1|2]Indicates the priority used for review

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