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Termination differences in the primary sensorimotor cortex between the medial lemniscus and spinothalamic pathways in the human brain

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ABSTRACT

The medial lemniscus (ML) and its thalamocortical pathway is responsible for proprioception, in contrast, the spinothalamic tract (ST) and its thalamocortical pathway is the neural tract for pain and body temperature. Therefore, the ML pathway plays a crucial role in skillful movements and may be more linked to motor function than the ST pathway. We investigated the differences in the distribution of the primary motor cortex (M1) and the primary somatosensory cortex (S1) between the ML and ST pathways. Adults (mean age: 40.4 years, range: 21–61 years) were recruited for this study. The seed masks for the ML and ST pathways were given on the color map of the medulla according to the known anatomy and waypoint masks were placed on the ventro-postero-lateral nucleus of the thalamus. The volume of ML pathway did not show any difference between the M1 (10.94) and S1 (13.02) ($p > 0.05$). By contrast, the mean voxel number of the ST pathway in the M1 (18.25) and S1 (27.38) showed significant difference between the M1 and S1 ($p < 0.05$). As for relative voxel number percentage of the M1 compared to the S1, the ML pathway (84%) was significantly higher than ST pathway (67%) ($p < 0.05$). We found that more neural fibers of the ML pathway were terminated in the M1 relative to the S1 compared to the SLP, and this may be linked to the inherent execution of movements of the M1.

It is well-known that movements requires somatosensory function as well as motor function. Many studies have reported that the neural tracts for motor function are closely linked with somatosensory neural tracts [17,19,32]. In the human brain, there are two main somatosensory pathways: the medial lemniscus (ML) and its thalamocortical pathway, and the spinothalamic tract (ST) and its thalamocortical pathway [21]. The ML pathway is responsible for proprioception, which functions in the conscious awareness of body position in space, as well as tactile discrimination [11,21]. By contrast, the ST pathway is the neural tract responsible for pain and body temperature [26,30]. Therefore, the ML pathway plays a crucial role in skillful movements and may be more closely linked to motor function than the ST pathway [9,14,25,35,40]. We hypothesized that there may be a difference in the distribution of the primary motor cortex (M1) and the primary somatosensory cortex (S1) between the ML and ST pathways.

Diffusion tensor tractography (DTT), which is derived from diffusion tensor imaging (DTI), allows the visualization and localization of the ML and ST pathways in three dimensions [20,23,24,27,42,43]. There has been no DTT study investigating the differences between ML and ST pathways in termination of the M1 and S1. In the current study, we investigated the differences between the ML and ST pathways for the distribution in the M1 and S1 using DTT.

Twenty-four right-handed healthy subjects (male: 14, female: 10, mean age: 40.4 years, range: 21–61 years) with no previous history of neurological, psychiatric, or physical illness were enrolled in this study. Handedness was evaluated using the Edinburg Handedness Inventory [31]. All subjects understood the purpose of the study and provided written, informed consent. The study protocol was approved by the local Institutional Review Board.

Diffusion-weighted imaging data were obtained using a 1.5-T Philips Gyroscan Intera system equipped with a synergy-L Sensitivity Encoding (SENSE) head coil utilizing a single-shot, spin-echo planar imaging pulse sequence. For each of the 32 non-collinear diffusion sensitizing gradients, we acquired 67 contiguous slices parallel to the anterior commissure (AC) – posterior commissure (PC) line. Imaging parameters were as follows: acquisition matrix = 96 × 96, reconstructed to matrix = 128 × 128 matrix,

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field of view = 221 × 221 mm^2, TR = 10,726 ms, TE = 76 ms, parallel imaging reduction factor (SENSE factor) = 2, EPI factor = 49 and b = 1000 s/mm^2, NEX = 1, and a slice thickness of 2.3 mm.

The Oxford Centre for Functional Magnetic Resonance Imaging of the Brain (FMRIB) Software Library (Oxford Centre for Functional MRI of the Brain, FSL, UK; www.fmrib.ox.ac.uk/fsl) was used for analysis of DTI data. Head motion effect and image distortion due to eddy current were corrected by realignment of every DTI volume image to a b = 0 volume image using affine multi-scale two-dimensional registration [37]. A probabilistic tractography method based on a multi-tensor model was used in performance of fiber tracking; the method was applied in the present study using tractography routines implemented in FMRIB Diffusion (5000 streamline samples, 0.5 mm step lengths, curvature thresholds = 0.2) [6,7]. The seed masks for the ML and SLP were given on the color map according to the known anatomy of the ML and ST pathways on the brain of each subject the ML pathway: the ML pathway area of the anteromedial medulla, the ST pathway: the ST pathway area of the posterolateral medulla (posterior to the inferior olivary nucleus, anterior to the inferior cerebellar peduncle, and lateral to the ML pathway) [24,30,36]. A waypoint mask was drawn around the ventro-postero-lateral (VPL) nucleus of the thalamus, which was placed at one third of the AC-PC line from the PC for the antero-posterior direction and three-fourths of the thalamus from the AC-PC line for the mediolateral direction, where this mask was located in the purple area on a color-coded primary diffusion map [13,29]. The number of the voxels of each seed mask was counted. Of the 5000 samples generated from each seed voxel, the results for each contact were visualized at a minimum threshold of one streamline and a maximum of 5000 streamlines per voxel for

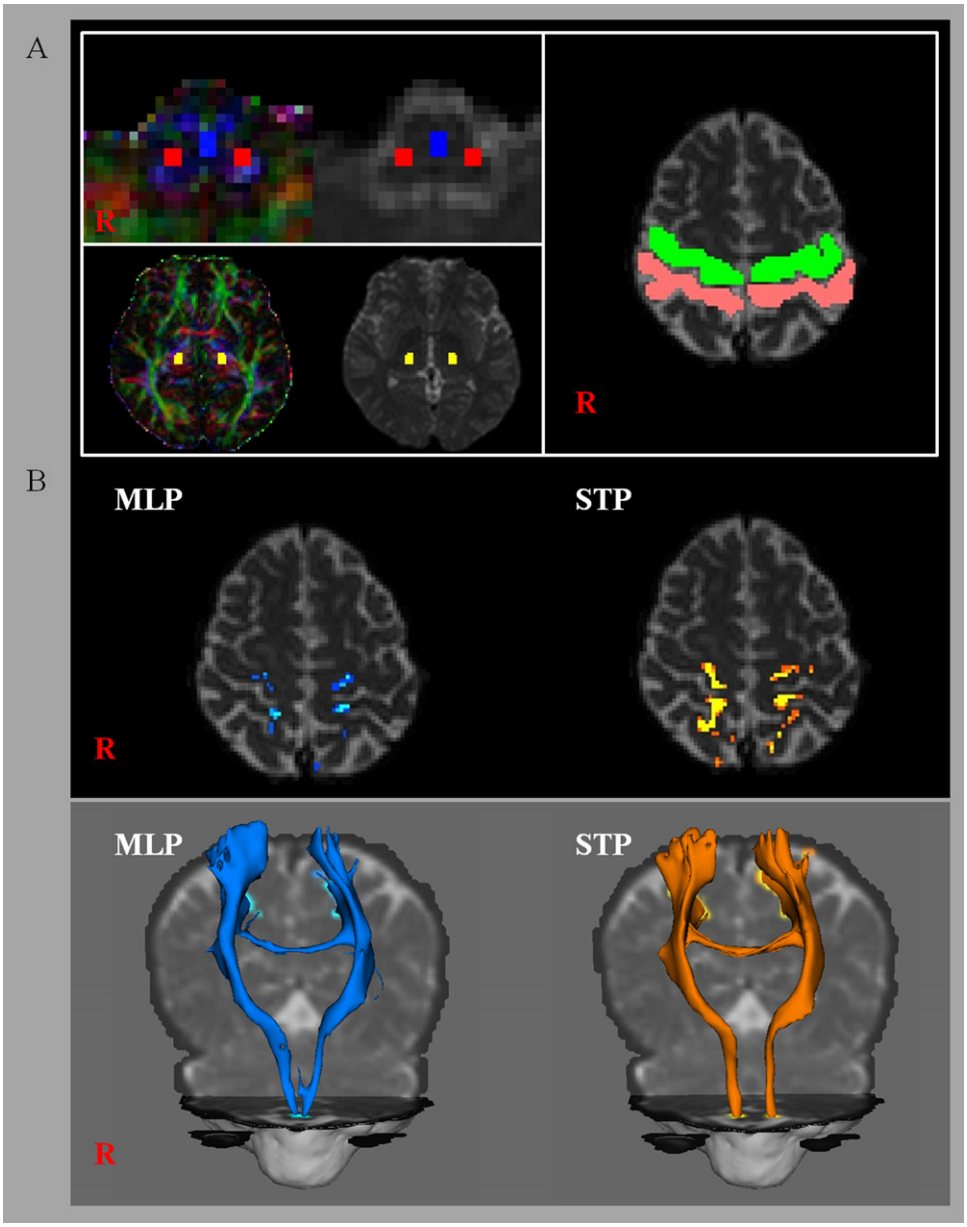

Fig. 1. (A) The seed masks are given on the anteromedial medulla (medial lemniscus [ML] and its thalamocortical pathway; blue) and the posterolateral medulla (spinothalamic tract [ST] and its thalamocortical pathway; red). The waypoint mask is located around the ventro-postero-lateral nucleus of the thalamus (yellow). The voxel numbers of the probabilistic maps are measured in the primary motor cortex (precentral gyrus: green) and the primary somatosensory cortex (postcentral gyrus: pink). (B) The probabilistic maps are color coded for 1 (blue and red) to 100 (sky blue and yellow) samples passing through the voxel. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)