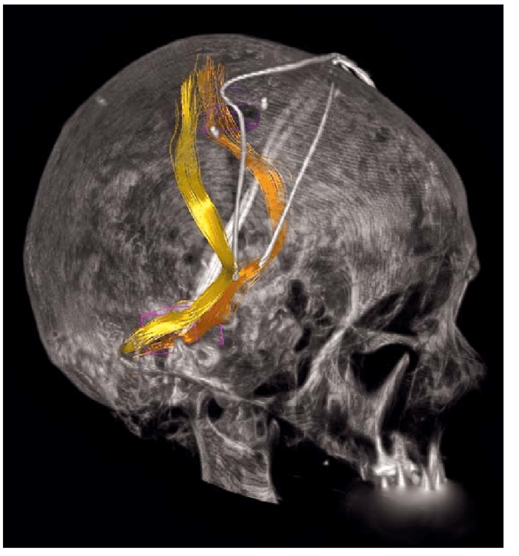
Dentatothalamic tract



The dentatothalamic tract (or dentatorubrothalamic tract) is a tract which connects the dentate nucleus and the thalamus while sending collaterals to the red nucleus.

The term “dentatorubrothalamocortical” is sometimes used to emphasize termination in the cerebral cortex.

The dentatothalamic tract or dentatorubrothalamic tract (DRTT) originates from the dentate nucleus in the cerebellum and terminates in the contralateral ventral lateral nucleus (VL) of the thalamus after decussating to the contralateral red nucleus. Identification of the DRTT is difficult due to the fact that it is a long, multisynaptic, neural tract crossing to the opposite hemisphere.

The trajectory and lateralization of the d-DRTT were explored using data from subjects in the Massachusetts General Hospital-Human Connectome Project adult diffusion dataset. The afferent and efferent networks that compose the cerebello-thalamo-cerebral pathways were also reconstructed. Correlation analysis was performed to identify interrelationships between subdivisions of the cerebello-dentato-rubro-thalamic and thalamo-cerebral connections. The d-DRTT was visualized bilaterally in 28 subjects. According to a normalized quantitative anisotropy and lateralization index evaluation, the left and right d-DRTT were relatively symmetric. Afferent regions were found mainly in the posterior cerebellum, especially the entire lobule VII (crus I, II and VIIb). Efferent fibers mainly are projected to the contralateral frontal cortex, including the motor and nonmotor regions. Correlations between cerebello-thalamic connections and thalamo-cerebral connections were positive, including the lobule VIIa (crus I and II) to the medial prefrontal cortex (MPFC) and the dorsolateral prefrontal cortex and lobules VI, VIIb, VIII, and IX, to the MPFC and motor and premotor areas. These results provide DSI-based tratographic evidence showing segregated and parallel cerebellar outputs to cerebral regions. The posterior cerebellum may play an important role in supporting and handling cognitive activities through d-DRTT. Future studies will allow for a more comprehensive understanding of cerebello-cerebral connections [1)].

The dentato-rubro-thalamic tract (DRTT) regulates motor control, connecting the cerebellum to the thalamus.

Cerebellar mutism can occur in a third of children undergoing cerebellar resections. Recent evidence proposes it may arise from uni- or bilateral damage of cerebellar efferents to the cortex along the dentatothalamic tract. At present, no neurophysiological procedure is available to monitor this pathway intraoperatively. Giampiccolo et al. specifically aimed at filling this gap.

They assessed 10 patients undergoing posterior fossa surgery using a conditioning-test stimulus paradigm. Electrical conditioning stimuli (cStim) were delivered to the exposed cerebellar cortex at interstimulus intervals (ISIs) of 8-24 ms prior to transcranial electric stimulation of the motor cortex, which served as test stimulus (tStim). The variation of motor-evoked potentials (MEP) to cStim + tStim compared with tStim alone was taken as a measure of cerebello-cortical connectivity.

cStim alone did not produce any MEP. cStim preceding tStim produced a significant inhibition at 8 ms ($p < 0.0001$) compared with other ISIs when applied to the lobules IV-V-VI in the anterior cerebellum and the lobule VIIB in the posterior cerebellum. Mixed-effects of decrease and increase in MEP amplitude were observed in these areas for longer ISIs.

The inhibition exerted by cStim at 8 ms on the motor cortex excitability is likely to be the product of activity along the cerebello-dento-thalamo-cortical pathway. They showed that monitoring efferent cerebellar pathways to the motor cortex is feasible in intraoperative settings. This study has promising implications for pediatric posterior fossa surgery with the aim to preserve the cerebello-cortical pathways and thus prevent cerebellar mutism [2).].

This tract is modulated by deep brain stimulation in the surgical treatment of medically refractory tremor, especially in essential tremor, where high-frequency stimulation of the thalamus can improve symptoms. The DRTT is classically described as a decussating pathway, ascending to the contralateral thalamus. However, the existence of a nondecussating (i.e. ipsilateral) DRTT in humans was recently demonstrated, and these tracts are arranged in distinct regions of the superior cerebellar peduncle.

Petersen et al., hypothesized that the ipsilateral DRTT is connected to specific thalamic nuclei and therefore may have unique functional relevance. The goals of this study were to confirm the presence of the decussating and nondecussating DRTT pathways, identify thalamic termination zones of each tract, and compare whether structural connectivity findings agree with functional connectivity. Diffusion-weighted imaging was used to perform probabilistic tractography of the decussating and nondecussating DRTT in young healthy subjects from the Human Connectome Project ($n = 91$) scanned using multi-shell diffusion-weighted imaging (270 directions; TR/TE = 5500/89 ms; spatial resolution = 1.25 mm isotropic). To define thalamic anatomical landmarks, a segmentation procedure based on the Morel stereotactic atlas of the human thalamus was employed, and DRTT targeting was quantified based on the proportion of streamlines arriving at each nucleus. In parallel, functional connectivity analysis was performed using resting-state functional MRI (TR/TE = 720/33 ms; spatial resolution = 2 mm isotropic). It was found that the decussating and nondecussating DRTTs have significantly different thalamic endpoints, with the former preferentially targeting relatively anterior and lateral thalamic nuclei, and the latter connected to more posterior and medial nuclei ($p < 0.001$). Functional and structural connectivity measures were found to be significantly correlated ($r = 0.45$, $p = 0.031$). These findings provide new insight into pathways through which unilateral cerebellum can exert bilateral influence on movement and raise questions about the functional implications of ipsilateral cerebellar efferents [3)].

Pineda-Pardo et al., published a cohort of 24 essential tremor patients before and 3 months after unilateral transcranial magnetic resonance guided focused ultrasound targeting at the posteroventral part of the VIM. Microstructural changes along the dentatorubrothalamic tract (DRTT) were quantified by means of probabilistic tractography, and later related to the clinical improvement of the patients at 3-months and at 1-year after the intervention. In addition the changes along two neighboring tracts, that is, the corticospinal tract and the medial lemniscus, were assessed, as well as the relation between these changes and the presence of side effects. Thalamic lesions produced local and distant alterations along the trajectory of the DRTT, and each correlated with clinical improvement. Regarding side effects, gait imbalance after thalamotomy was associated with greater impact on the DRTT, whereas the presence of paresthesias was significantly related to a higher overlap between the lesion and the medial lemniscus. This work represents the largest series describing the microstructural changes following transcranial MR-guided focused ultrasound thalamotomy in essential tremor. These results suggest that clinical benefits are specific for the impact on the cerebello-thalamo-cortical pathway, thus reaffirming the potential of tractography to aid thalamotomy targeting [4)].

Diffusion tensor imaging was performed at 1.5-T using a synergy-L sensitivity encoding head coil. DRTTs were obtained by selection of fibers passing through three regions of interest (the dentate nucleus, the superior cerebellar peduncle, and the contralateral red nucleus) from 41 healthy volunteers. Probabilistic mapping was obtained from the highest probabilistic location at 2.3 mm above the anterior commissure-posterior commissure level.

DRTTs of all subjects, which originated from the dentate nucleus, ascended through the junction of the superior cerebellar peduncle and the contralateral red nucleus and then terminated at the VL nucleus of the thalamus. The highest probabilistic location for the DRTT at the thalamus was compatible with the location of the VL nucleus.

Kwon et al identified the DRTT in the human brain using probabilistic tractography. Our results could be useful in research on movement control [5)]

The dentatorubrothalamic tract (DRTT) is the major efferent cerebellar pathway arising from the dentate nucleus (DN) and decussating to the contralateral red nucleus (RN) and thalamus. Surprisingly, hemispheric cerebellar output influences bilateral limb movements. In animals, uncrossed projections from the DN to the ipsilateral RN and thalamus may explain this phenomenon. The aim of a study was to clarify the anatomy of the dentatorubrothalamic connections in humans.

Meola et al applied advanced deterministic fiber tractography to a template of 488 subjects from the Human Connectome Project (Q1-Q3 release, WU-Minn HCP consortium) and validated the results with microsurgical dissection of cadaveric brains prepared according to Klingler's method.

The authors identified the “classic” decussating DRTT and a corresponding nondecussating path (the nondecussating DRTT, nd-DRTT). Within each of these 2 tracts some fibers stop at the level of the RN, forming the dentatorubro tract and the nondecussating dentatorubro tract. The left nd-DRTT encompasses 21.7% of the tracts and 24.9% of the volume of the left superior cerebellar peduncle, and the right nd-DRTT encompasses 20.2% of the tracts and 28.4% of the volume of the right superior cerebellar peduncle.

The connections of the DN with the RN and thalamus are bilateral, not ipsilateral only. This affords a potential anatomical substrate for bilateral limb motor effects originating in a single cerebellar hemisphere under physiological conditions, and for bilateral limb motor impairment in hemispheric cerebellar lesions such as ischemic stroke and hemorrhage, and after resection of hemispheric tumors and arteriovenous malformations. Furthermore, when a lesion is located on the course of the dentatorubrothalamic system, a careful preoperative tractographic analysis of the relationship of the DRTT, nd-DRTT, and the lesion should be performed in order to tailor the surgical approach properly and spare all bundles [6].

References

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