Subthalamic nucleus anatomy

The subthalamic nucleus is a small lens-shaped nucleus in the brain where it is, from a functional point of view, part of the basal ganglia system.

Located ventral to the thalamus. It is also dorsal to the substantia nigra and medial to the internal capsule. It was first described by Jules Bernard Luys in 1865, and the term corpus Luysi or Luys' body is still sometimes used.

Güngör et al., aimed to delineate the 3D anatomy of the STN and unveil the complex relationship between the anatomical structures within the STN region using fiber dissection technique, 3D reconstructions of high-resolution MRI, and fiber tracking using Diffusion Tensor Imaging Tractography utilizing a generalized q-sampling imaging (GQI) model.

Fiber dissection was performed in 20 hemispheres and 3 cadaveric heads using the Klingler method. Fiber dissections of the brain were performed from all orientations in a stepwise manner to reveal the 3D anatomy of the STN. In addition, 3 brains were cut into 5-mm coronal, axial, and sagittal slices to show the sectional anatomy. GQI data were also used to elucidate the connections among hubs within the STN region.

The study correlated the results of STN fiber dissection with those of 3D MRI reconstruction and tractography using neuronavigation. A 3D terrain model of the subthalamic area encircling the STN was built to clarify its anatomical relations with the putamen, globus pallidus internus, globus pallidus externus, internal capsule, caudate nucleus laterally, substantia nigra inferiorly, zona incerta superiorly, and red nucleus medially.

They also described the relationship of the medial lemniscus, oculomotor nerve fibers, and the medial forebrain bundle with the STN using tractography with a 3D STN model.

This study examines the complex 3D anatomy of the STN and peri-subthalamic area. In comparison with previous clinical data on STN targeting, the results of this study promise further understanding of the structural connections of the STN, the exact location of the fiber compositions within the region, and clinical applications such as stimulation-induced adverse effects during DBS targeting [1)].

Mavridis et al., used cerebral magnetic resonance images (MRIs) from 26 neurosurgical patients and for the anatomic study 32 cerebral hemispheres from 18 normal brains from cadaver donors. They measured and analyzed the STN dimensions (based on its stereotactic coordinates).

At stereotactic level Z = -4, the STN length was 7.7 mm on MRIs and 8.1 mm in anatomic specimens. Its width was 6 mm on MRIs and 6.3 mm in anatomic specimens. The STN was averagely visible in 3.2 transverse MRI slices and its maximum dimension was 8.5 mm. The intercommissural distance was 26.3 mm on MRIs and 27.3 mm in anatomic specimens. They found statistically significant difference of the STN width and length between individuals <60 and ≥60 years old.

The identification of the STN limits was easier in anatomic specimens than on MRIs and easier on T2

compared to T1-weighted MRIs sections. STN dimensions appear slightly smaller on MRIs. Younger people have wider and longer STN [2].

Structure

The principal type of neuron found in the subthalamic nucleus has rather long sparsely dendritic spines.

The dendritic arborizations are ellipsoid, replicating in smaller dimension the shape of the nucleus.

The dimensions of these arborizations (1200,600 and 300 µm) are similar across many species—including rat, cat, monkey and human—which is unusual. However, the number of neurons increases with brain size as well as the external dimensions of the nucleus. The principal neurons are glutamatergic neurons, which give them a particular functional position in the basal ganglia system. In humans there are also a small number (about 7.5%) of GABAergic interneurons that participate in the local circuitry; however, the dendritic arborizations of subthalamic neurons shy away from the border and majorly interact with one another [3].

Divisions

The STN has been divided into three distinct subdivisions, motor, limbic, and associative parts in line with the concept of parallel information processing. The extent to which the parallel information processing coming from distinct cortical areas overlaps in the different territories of the STN is still a matter of debate and the proposed role of dopaminergic neurons in maintaining the coherence of responses to cortical inputs in each territory is not documented.

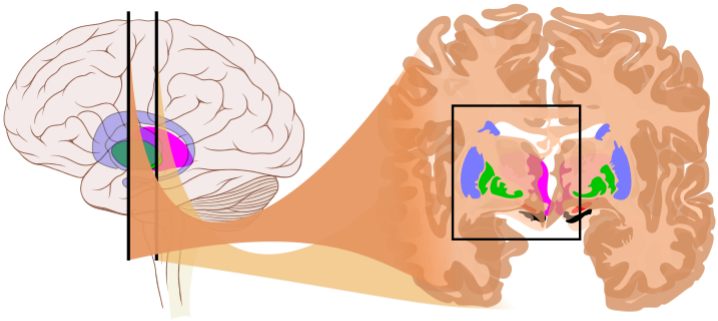
Afferent axons

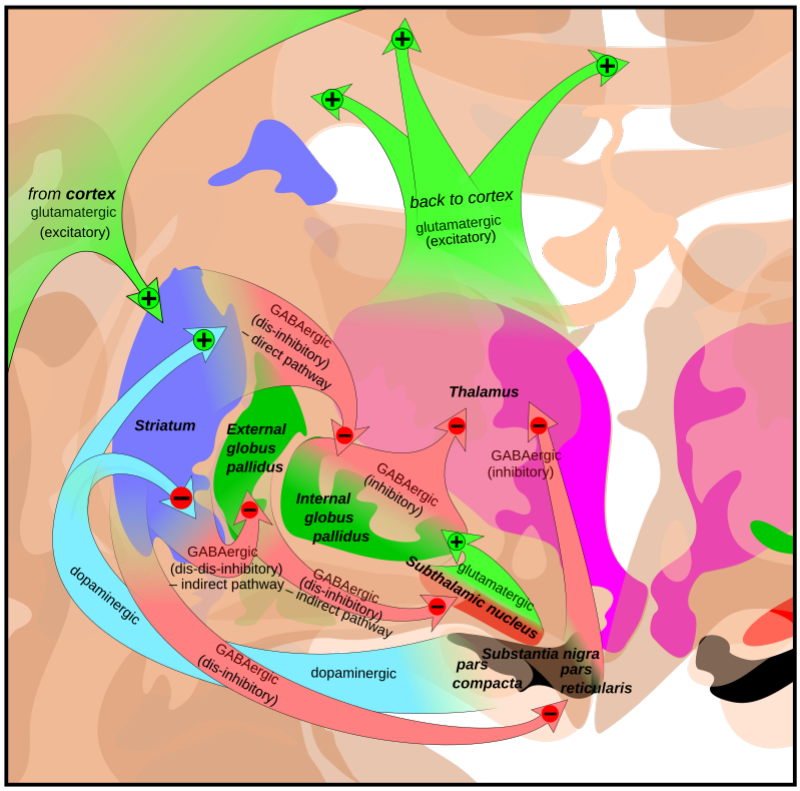
The subthalamic nucleus (STN) receives monosynaptic glutamatergic afferents from different areas of the cortex, known as the “hyperdirect” pathway.

The subthalamic nucleus receives its main input from the globus pallidus, not so much through the ansa lenticularis as often said but by radiating fibers crossing the medial pallidum first and the internal capsule.

These afferents are GABAergic, inhibiting neurons in the subthalamic nucleus.

Excitatory, glutamatergic inputs come from the cerebral cortex (particularly the motor cortex), and from the pars parafascicularis of the central complex. The subthalamic nucleus also receives neuromodulatory inputs, notably dopaminergic axons from the substantia nigra pars compacta. It also receives inputs from the pedunculopontine nucleus.





References

1)

Güngör A, Baydın ŞS, Holanda VM, Middlebrooks EH, Isler C, Tugcu B, Foote K, Tanriover N. Microsurgical anatomy of the subthalamic nucleus: correlating fiber dissection results with 3-T magnetic resonance imaging using neuronavigation. J Neurosurg. 2018 Apr 1:1-17. doi: 10.3171/2017.10.JNS171513. [Epub ahead of print] PubMed PMID: 29726781.

2)

Mavridis I, Boviatsis E, Anagnostopoulou S. Anatomy of the human subthalamic nucleus: a combined morphometric study. Anat Res Int. 2013;2013:319710. doi: 10.1155/2013/319710. Epub 2013 Dec 15. PubMed PMID: 24416591; PubMed Central PMCID: PMC3876692.

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https://en.wikipedia.org/wiki/Subthalamic_nucleus