The subthalamic nucleus and the globus pallidus internus: A micro-anatomical comparison and its implications for Deep Brain Stimulation

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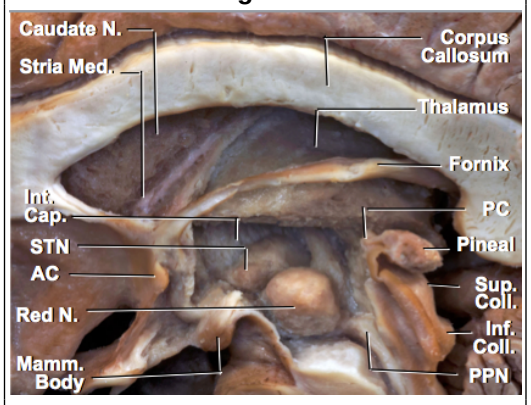
Introduction

Although much has been published regarding the selection of subthalamic nucleus(STN) versus globus pallidus internus(GPi) as targets of deep brain stimulation(DBS) for Parkinson's Disease, there are no anatomical dissection studies comparing both structures and their pathways. This study aims to dissect the STN and the GPi and their associated fiber pathways to clarify the microanatomy, then correlate this anatomy with observations of differential stimulation-induced side effects between the two targets.

Methods

Ten cadaveric human brains and two cadaveric heads were examined using fiber dissection techniques, under x6 and x40 magnification. The STN and GPi were dissected from inferior, superior, lateral and medial aspects to study their anatomy and fiber connections (Figures 1 and 2). Before dissecting the heads, stereotactic targeting of the STN and GPi were performed (Figures 3 and 4). Tractography was conducted using 3T and 4.7T MRI (Figure 5).

Figure 1

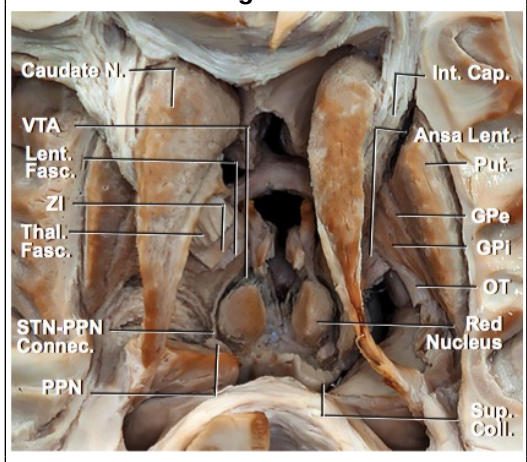


Fiber Dissection Medial to lateral: Subthalamic Nucleus and its relationships.

Results

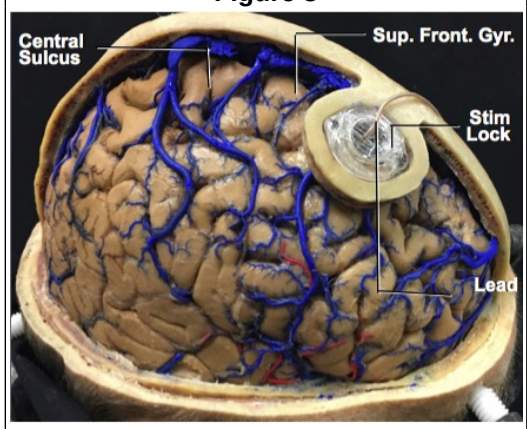
The internal capsule(IC), GPi and globus pallidus externus(GPe) connect along the anterolateral border of the STN. The substantia innominata and pre-frontal cortex connect to STN anteriorly; the zona incerta(ZI) dorsally; the red nucleus, substantia nigra pars reticulata(SNr) and the pedunculopontine nucleus(PPN) inferomedially. The GPi is connected to GPe laterally; the IC posteromedially and ansa lenticularis inferiorly. The most important fiber connections from the GPi are to SNr, ZI, STN, PPN, cortex, thalamus and GPe (Figures 1 and 2). The nine connections related to the STN and the seven related to the GPi were summarized. This is the first study demonstrating these connections using anatomical micro-dissection and tractography (Figures 3, 4 and 5). The anatomic findings are briefly analyzed in relation to various stimulation-induced side effects (Figure 4).

Figure 2



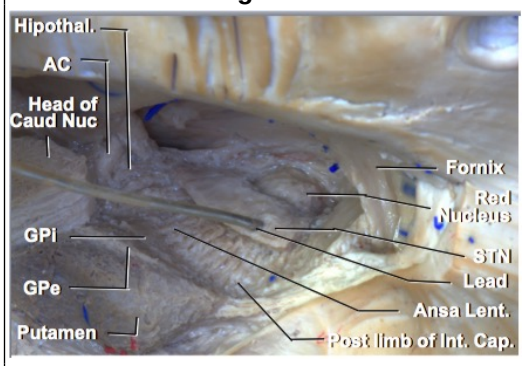
Fiber Dissection Superior to Inferior: STN and GPi connections and relationships.

Figure 3



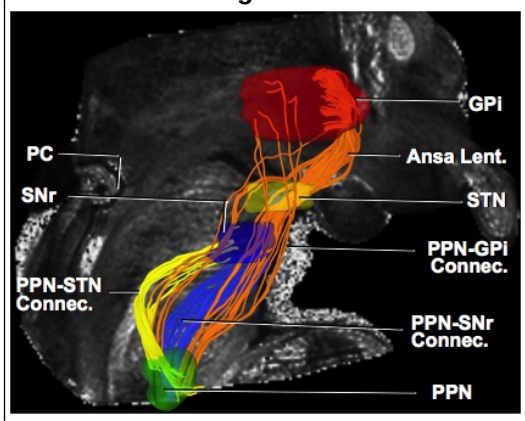
Stereotactic Model: note the drilling around the Stim Lock to prevent skin erosions.

Figure 4



The lead targetting the STN on its postero-lateral portion.

Figure 5



Tractrography using 4.7T MRI to show STN, GPi and PPN connections.

Conclusions

Precise knowledge of the neuroanatomy, anatomical relationships and fiber connections of the STN and GPi will enable more effective targeting and improved outcomes of DBS. Further studies are underway to anatomically explain each side effect of stimulation observed intra-operatively and during DBS programming.