

Mapping of Nucleus Basalis of Meynert Projections Using Diffusion Tensor Imaging for Neurosurgical Needs

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Introduction

Based on numerous preclinical studies and a few successful case reports, the nucleus basalis of Meynert (NBM) has drawn attention as a potential target for neuromodulation in degenerative dementia disorders. The NBM has a clear role in cognition, including attention, arousal, memory, and perception. The loss of cholinergic neurons in this nucleus directly correlates with the level of cognitive impairment in both Parkinson's disease (PD) dementia and Alzheimer's disease. The NBM is a thin flat irregular structure in the axial plane of the basal forebrain. The diffuse NBM projections originate from MRIinvisible subnuclei that are "subspecialized" to serve certain domains of cognition. The detailed diffusion tensor imaging (DTI) maps of NBM subnuclear connectivity that are necessary for DBS targeting, are currently unavailable. Our pilot study was designed to help address this challenge in preparation for the investigation of the effects of NBM deep brain stimulation (DBS) for the treatment of PD dementia.

Methods

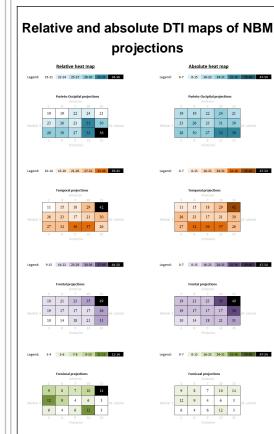
We studied the diffusion-weighted MRIs of 9 patients who underwent DBS surgery for PD. We divided the NBM area into 15 segments with 4 mm diameter each to mimic the brain volumes of DBS tissue activation. Deterministic DTI tractography seedings were done from each segment. The projections were quantified by their fiber density. Probability heat maps for different types of projections were created and the resultant patterns were analyzed and correlated with dementia rating scale (DRS) scores.

Results

The hand segmentation of the NBM introduced some variability. Nonetheless, we found a weak correlation (r = 0.31) between the left NBM volume and the DRS score. The right NBM volume also showed a weak but negative correlation (r = -0.2)with the DRS score. Several patterns in the NBM projectional probability heat map were recognized. The densest projections seemed to stem from the anterolateral segment of the NBM (the range of coordinates relative to the midcommissural point: lateral 23 to 30.6, AP 10.9 to 20, vertical -3.8 to -12.7 mm) except parietooccipital projections, which arise from the posterolateral segment of the NBM. The paucity of forniceal projections and the lack of cingulate projections can be attributed to the limitations of deterministic DTI tractography. We did not find correlations between the NBM projectional fiber volumes and DRS scores in our study.

Conclusions

We developed the reproducible methodology to visualize strong parieto-occipital, frontal, and temporal projections of the NBM. Our study illustrates that DTI, although not perfect, is still a powerful and practical tool for fine tuning the coordinates of complex novel neuromodulation targets such as the NBM. The lateral portion of the NBM (esp. its anterior part) seems to be a good DBS target to encompass the maximum of NBM projections.

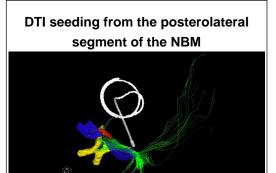


The NBM DTI probability heat maps for different types of projections, irrespective of cognitive level or laterality. The theoretical maximum for each segment is 54 points.

References

1. Barnikol, T.T., Pawelczyk, N.B.A., Barnikol, U.B., Kuhn, J., Lenartz, D., Sturm, V., Tass, P.A., Freund, H.-J., 2010. Changes in apraxia after deep brain stimulation of the nucleus basalis Meynert in a patient with Parkinson dementia syndrome. Mov.Disord. 25, 1519-1520. 2. Gratwicke J1, Kahan J, Zrinzo L, Hariz M, Limousin P, Foltynie T, Jahanshahi M.: The nucleus basalis of Meynert: a new target for deep brain stimulation in dementia? Neurosci Biobehav Rev. 2013 Dec; 37(10 Pt 2): 2676-88. 3. Hardenacke K1, Kuhn J, Lenartz D, Maarouf M, Mai JK, Bartsch C, Freund HJ, Sturm V.: Stimulate or degenerate: deep brain stimulation of the nucleus basalis Meynert in Alzheimer dementia. World Neurosurg. 2013 Sep-Oct;80(3-4):S27.e35-43.

4. Teipel, S.J., Meindl, T., Grinberg, L., Grothe, M., Cantero, J.L., Reiser, M.F., Möller, H.-J., Heinsen, H., Hampel, H., 2011. The cholinergic system in mild cognitive impair-ment and Alzheimer's disease: an in vivo MRI and DTI study. Hum. Brain Mapp.32, 1349–1362.



Parieto-occipital, frontal, temporal, and forniceal projections (green) with 4x4x4 mm DTI seeding box in the posterolateral segment of the left NBM. Bilateral NMBs (blue), optic chiasm (yellow), anterior commissure (red), and the actual DBS lead (white) in the left GPi are segmented to illustrate the spatial relationships.