Preservation of Deep Gray Nuclear Tissue Contrast and Utility of Thalamus as an Internal Standard in Inversion Recovery MR Images at High and Low RF Power in Parkinson's Patients Treated with Deep Brain Neurostimulators

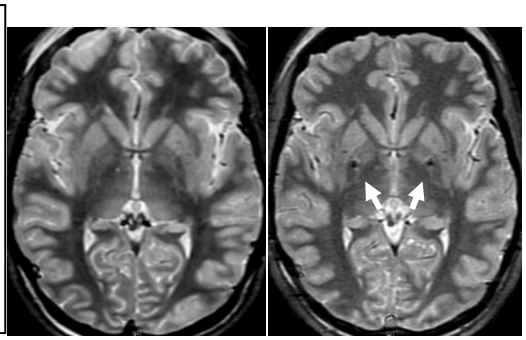
Subhendra Sarkar[1], Ron Alterman[2], Rafael Rojas[1], Douglas Teich[1], Jeremy Stormann[1], Ines Cabral-Goncalves[1], David Hackney[1], and Efstathios Papavassiliou[2]
[1]*Radiology, Beth Israel Deaconess Medical Center, Harvard Medical School, BOSTON, Massachusetts, United States,* [2]*Surgery, Beth Israel Deaconess Medical Center, Harvard Medical School, BOSTON, Massachusetts, United States*

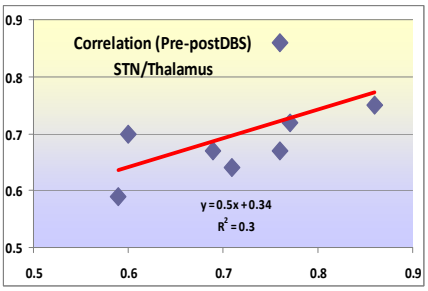
Purpose: Localization and targeting of brain nuclei during deep brain stimulation (DBS) surgery using standard atlas coordinates cannot be generalized to all patient groups and currently microelectrode recording is absolutely needed to provide real-time and space confirmation for lead placement (1). Direct MR detection of nuclei is promising although it reveals variation in nuclei positions and dimensions in the range of the nucleus size due to a variety of factors that question the rationale of using standard nuclear coordinates during DBS surgery (2). Due to the increasing role of MRI to influence the accuracy of the anatomically derived coordinates we assessed the relative tissue contrast and thereby the localization accuracy of the deep nuclei using FSE Inversion Recovery (3). MR tissue contrast variation of these nuclei is significant in Parkinson's patients that we feel are due to variability in MR hardware and software used, disease processes and age dependent changes in nuclei composition. It may be useful to develop an internal standard (thalamus as proposed here) to assess contrast variation and therefore directly localize deep nuclei before and after DBS implantation in such patients. We have extended a 3D low-SAR approach (4) to 2D FSEIR sequence to minimize the RF heating risks (5) and tested the relation between tissue contrasts in pre-surgical high SAR images and those obtained at an order of magnitude lower SAR post-implantation.

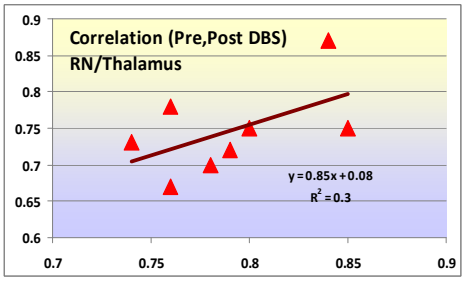
Methods: Using an IRB approved protocol low and high-SAR MR images (GE 1.5T) for 7 patients with progressive Parkinson's disease and one patient with torsion dystonia were evaluated pre and post-DBS implantation by a 3D MPRAGE and an optimized T_1w FSEIR sequence: NEX/TE/TI/Voxel Size/TR/Refocusing FA/Scan Time/SAR level = 2/10ms/140ms/1x1x3mm^3/4s/Constant FA=180^0/ 5min for 30 slices (high SAR=1.5 W/kg, pre-DBS) and = 2/10ms/140ms/1x1x3 mm^3/7s/Variable FA=100-110^0/7min for 12-16 slices (low-SAR=0.1 W/kg, post-DBS). All DBS systems were deactivated and informed consents were obtained with explained risks prior to post-DBS MR. Images were assessed by 3 independent readers (one radiologist, one neurosurgeon and a physicist). The relation between tissue contrasts for low and high-SAR images for all four deep brain nuclei was assessed by computing the Pearson correlation coefficients of subthalamic nuclei (STN), red nuclei, putamen and globus pallidus after normalizing to thalamus in all 8 patients. R^2 >0.5 was judged as adequate to preserve nuclear contrast even after 15-fold SAR reduction.

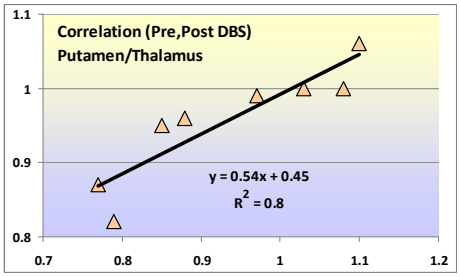
Results:

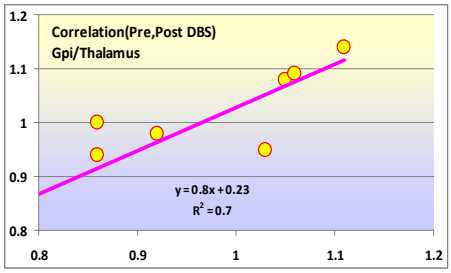
GPi/e are well visualized in high (1.5 W/kg) and in low-SAR (0.1 W/kg) images for a Parkinson's patient with bilateral DBS (arrows). No excess image blur or artifacts are present although slight loss of G/W contrast is evident in low-SAR image. Correlation plots shown here between low and high SAR images indicate $R^2 \approx 0.3$ (low) for Subthalamic and red nuclei and 0.7- 0.8 (high) for Putamen and GPi .











Discussion: This is the first work to use a SAR-intensive FSEIR sequence within a safe RF limit comparing deep gray nuclear contrasts normalized to an internal standard pre and post-DBS on Parkinson's patients. Because STN is a small, curved structure localization and intensity computation might have suffered from volume averaging leading to low correlation (0.3). GPi and putamen have simpler geometries and the low-SAR preserves 70-80% of contrasts. At higher fields (3T or 7T, Ref 6-7) and at a very high SAR while the nuclei are better seen than 1.5T, the true nuclear size may be distorted or exaggerated. However, if nuclear contrast can be maintained safely, the primary result of this work, low-SAR FSEIR is preferred to gradient echoes in high susceptibility environment post-DBS when tissue swelling, CSF loss and brain shifts often influence localization accuracy.

Conclusion: The 2D FSE low-SAR method ($\leq$ 0.1 W/kg) maintains the deep gray tissue contrasts for post-DBS patient group. Thalamic MR signal seems usable as an internal standard to confirm the nuclei borders before and after DBS implantation. Space confirmation with preserved nuclear contrast in a high susceptibility, post-surgical environment may improve direct MR targeting and reduce the role of microelectrode recording.

References : (1) Alterman et al. (Editorial) Movement Disord (2012);27:1348. (2) Daniluk et al. Acta Neurochir (2010);152: 201. (3) Kitajima et al. Neuroradiol (2008);50: 675. (4) Sarkar et al. Radiology (2011);259: 550. (5) Baker et al. JMRI (2006);24: 1236. (6) Schafer et al. Hum Br Mapp (2012);33: 2831. (7) Cho et al. J Neurosurg (2010);113: 639.