MR-guided Deep Brain Stimulator Implantation for Treating Tremor in PD Patient

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Objective Deep brain stimulator (DBS) implantation is a promising treatment alternative for suppressing tremor in Parkinson (PD) patient. Different from lesioning, DBS, which suppresses the motor symptom by stimulating a specific deep brain location at high frequency to interrupt the abnormal portion of the basal ganglia-thalamocortical motor circuit, is reversible and adjustable. The main hypothesis of the project is that the non-invasive and high soft-tissue contrast MR imaging can be effectively employed in the planning, guiding and monitoring a neurosurgical procedure for the implantation of DBS electrode. MRI is the only non-invasive imaging technique available today which allows a neurosurgeon to visualize the thalamic, pallidal & subthalamic structures, and AC/PC at sufficiently high spatial resolution and grey-white contrast for surgical planing and targeting. Furthermore, from 3-dimensional MR images, geometrical measurements can be made for targeting a specific site in the subthalamic area. In the presence of potential brain shift, the need for prospective MR guidance and monitoring becomes greater to maximize the accuracy of the targeting and reducing the risk of complication. The objects are 1) to develop a minimally invasive approach using high spatial resolution and soft-tissue contrast MR imaging techniques to guide the surgical placement of DBS, 2) to assess a combined high field MR and surgical suite (MROR) for its use in functional neurosurgical applications.

Methods A MR compatible Radionics stereotactic headframe (Fig.1) (Radionics, Burlington, Massachusetts) was used for DBS electrode (Thalamic and pallidal neurostimulators, Medtronic, Minneapolis, MN) placement. A short bore clinical 1.5T MR scanner (Philips Gyroscan ACS-NT/PowerTrack 6000) was used for intra-operative imaging and guidance. Two-element flexible phased array coils were used and integrated to the frame during the surgical prep. To minimize the susceptibility distortion artifact, an ultra short TE gradient echo sequence has been optimized without compromising Grey-White Matter contrast. In the MR-guided procedure, the MR images were used to obtain accurate geometrical measurements for stereotactically targeting a deep brain location. The neurosurgery was performed in the front of the magnet outside of the 10 Gauss line. Aided with positional registration cap assembly for the stereotactic headframe, the target location in thalamus was identified and measured from the MR images (Fig.2) in reference to the markers in the calibration cap of the headframe before the blurrhole prep. Subsequently, three orthogonal headframe coordinate settings were computed for setting up the stereotactic frame. These settings make the target point as the center of the frame. The trajectory guide on the two sliding tracks is designed to aim to the frame center while providing two extra degrees of freedom on a spherical surface. With these extra degrees of freedom, the trajectory guide can be easily adjusted to attain a best alignment to the entry point or the burr hole, through which a cannula is then advanced to the targeted location. Through the guide, the DBS electrode was later carefully introduced to the target under MR guidance and monitoring. The true electrode location was immediately verified using the susceptibility-suppressed, high resolution T1 imaging technique. On this image (Fig.3, 4), all four electrode terminals at the tip of the neurostimulator are clearly visible. The consequent neurostimulation showed an effective tremor suppression at a low stimulation voltage. A IR-FSE based imaging technique (TR/TE/TI=5000/20/170msec, ETL=9) with an exquisite grey-white matter contrast was an excellent MRI technique to show all the deep brain nucleuses.

Results In 5 patients (1 bi-thalamic), MR-guided DBS implantations have been performed according to the new approach. Intra-operative MRI provided the most updated morphological images with an excellent delineation basal ganglianic structures for surgeons to accurately target any specific areas. The target point can be identified and the necessary geometrical information can be obtained. The outcome showed that MRI has assured the successful placement of the DBS electrode in one shot in the complicated and risky procedure. Though the artifacts associated with the DBS electrode are severe on most standard imaging techniques, they can be effectively minimized, as well as used for visualization at 1.5T. This offers a unprecedented direct visualization the part of patient body under intervention, and most importantly it helps to void any critical structures in brain. Also any complications such as bleeding can be assessed in situ immediately prior to dural closure.

Conclusions MR-guided neurosurgery for DBS implantation at a high magnetic field strength has been shown to be feasible and desirable. It not only shortens the overall surgical procedural time significantly, but also promises better results for patients. Suitable MR techniques have been successfully developed, validated and used for the functional neurosurgery.

Reference P. A. Starr, Neurosurgery, 43:989-1015, 1998.

Figure 1,2,3,4 correpsond to upper-left, upper-right, lower-left and lower right respectively.