Deep brain stimulation lead placement

Intraoperative fluoroscopy and microelectrode recording (MER) are useful techniques for guiding deep brain stimulation lead placement (DBS). Recent advances in magnetic resonance imaging (MRI) have enabled information on the location of the basal ganglia, as the target of DBS, to be obtained preoperatively. However, intraoperative images with few artifacts are required to enable accurate fusion of preoperative imaging data with intraoperative lead position data. With the method of Atsumi et al., they first fuse preoperative MRI and pre-frame fixed computed tomography (CT) images, then fuse the CT images exactly after mounting the frame, using this fusion image as a platform image. Compared with before and after frame fixation, the pre-frame fixed CT has less artifacts, facilitating the identification of soft tissues such as the ventricles and cortical surface on pre-frame fixed CT images. By fusing the structural information for these soft tissues between pre-frame fixed CT and MR images, this fusion process can provide improved accuracy that is intuitively understood by the surgeon. Using platform images, surgical planning and intraoperative lead positioning can then be evaluated on the same coordinate axis. Positional data on the lead acquired as three-dimensional (3D) data are then added to the platform image. The proposed surgical steps permit the acquisition of accurate lead position data [1)].

Lead placement for deep brain stimulation (DBS) using Intraoperative magnetic resonance imaging (iMRI) relies solely on real-time intraoperative neuroimaging to guide electrode placement, without microelectrode recording (MER) or Electrostimulation. There is limited information, however, on outcomes after iMRI-guided DBS for dystonia. Sharma et al. evaluated clinical outcomes and targeting accuracy in patients with dystonia who underwent lead placement using an iMRI targeting platform.

Patients with dystonia undergoing iMRI-guided lead placement in the globus pallidus pars internus (GPi) were identified. Patients with a prior ablative or MER-guided procedure were excluded from clinical outcomes analysis. Burke-Fahn-Marsden Dystonia Rating Scale (BFMDRS) scores and Toronto Western Spasmodic Torticollis Rating Scale (TWSTRS) scores were assessed preoperatively and at 6 and 12 months postoperatively. Other measures analyzed include lead accuracy, complications/adverse events, and stimulation parameters.

A total of 60 leads were implanted in 30 patients. Stereotactic lead accuracy in the axial plane was 0.93 ± 0.12 mm from the intended target. Nineteen patients (idiopathic focal, n = 7; idiopathic segmental, n = 5; DYT1, n = 1; tardive, n = 2; other secondary, n = 4) were included in clinical outcomes analysis. The mean improvement in BFMDRS score was 51.9% ± 9.7% at 6 months and 63.4% ± 8.0% at 1 year. TWSTRS scores in patients with predominant cervical dystonia (n = 13) improved by 53.3% ± 10.5% at 6 months and 67.6% ± 9.0% at 1 year. Serious complications occurred in 6 patients (20%), involving 8 of 60 implanted leads (13.3%). The rate of serious complications across all patients undergoing iMRI-guided DBS at the authors' institution was further reviewed, including an additional 53 patients undergoing GPi-DBS for Parkinson's disease. In this expanded cohort, serious complications occurred in 11 patients (13.3%) involving 15 leads (10.1%).

Intraoperative MRI-guided lead placement in patients with dystonia showed improvement in clinical outcomes comparable to previously reported results using awake MER-guided lead placement. The accuracy of lead placement was high, and the procedure was well tolerated in the majority of patients. However, a number of patients experienced serious adverse events that were attributable to

the introduction of a novel technique into a busy neurosurgical practice, and which led to the revision of protocols, product inserts, and on-site training [2].

Deep brain stimulation (DBS) is a highly efficacious treatment option for movement disorders and a growing number of other indications are investigated in clinical trials. To ensure optimal treatment outcome, exact electrode placement is required. Moreover, to analyze the relationship between electrode location and clinical results, a precise reconstruction of electrode placement is required, posing specific challenges to the field of neuroimaging. Since 2014 the open source toolbox Lead-DBS is available, which aims at facilitating this process. The tool has since become a popular platform for DBS imaging. With support of a broad community of researchers worldwide, methods have been continuously updated and complemented by new tools for tasks such as multispectral nonlinear registration, structural/functional connectivity analyses, brain shift correction, reconstruction of microelectrode recordings and orientation detection of segmented DBS leads. The rapid development and emergence of these methods in DBS data analysis require us to revisit and revise the pipelines introduced in the original methods publication. Here we demonstrate the updated DBS and connectome pipelines of Lead-DBS using a single patient example with state-of-the-art high-field imaging as well as a retrospective cohort of patients scanned in a typical clinical setting at 1.5T. Imaging data of the 3T example patient is co-registered using five algorithms and nonlinearly warped into template space using ten approaches for comparative purposes. After reconstruction of DBS electrodes (which is possible using three methods and a specific refinement tool), the volume of tissue activated is calculated for two DBS settings using four distinct models and various parameters. Finally, four whole-brain tractography algorithms are applied to the patient's preoperative diffusion MRI data and structural as well as functional connectivity between the stimulation volume and other brain areas are estimated using a total of eight approaches and datasets. In addition, we demonstrate impact of selected preprocessing strategies on the retrospective sample of 51 PD patients. We compare the amount of variance in clinical improvement that can be explained by the computer model depending on the method of choice. This work represents a multi-institutional collaborative effort to develop a comprehensive, open source pipeline for DBS imaging and connectomics, which has already empowered several studies, and may facilitate a variety of future studies in the field [3].

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