

Comparison of Targeting Accuracy with Conventional and MR Guided Deep Brain Stimulator Implantation

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Introduction

Deep brain stimulators (DBS) are surgically implanted devices that are presently used to treat movement disorders such as Parkinson's disease (PD). Additional indications for deep brain stimulation, including other movement disorders, epilepsy, depression, obsessive compulsive disorders, and Tourette's syndrome, are rapidly emerging. For maximal efficacy, DBS electrodes must be precisely positioned within a target brain structure that is specific to the treated disease. Conventional DBS electrode insertion is performed stereotactically and is supplemented by intraoperative physiologic mapping to help refine electrode position. This requires an awake, cooperative patient and the insertion of microelectrodes into the brain to perform physiologic mapping.

We have developed an alternate approach for implantation of DBS electrodes that utilizes intraoperative MR guidance. This approach has several significant advantages, including the ability to directly visualize the deep brain target and confirm technical success prior to completion of the surgery. It may obviate the need for invasive physiologic tests on awake patients and therefore open the therapy up to a wider range of patients and clinical conditions. It further has the potential to substantially simplify and shorten the operative procedure, minimize the risk of hemorrhagic complications due to fewer brain penetrations, and result in more accurate and consistent DBS electrode positioning. The purpose of this study was to evaluate and compare the targeting accuracy that can be achieved with conventional stereotactic implantation to that which has been achieved with MR guidance.

Methods

A total of 29 PD patients have undergone MR guided DBS electrode implantation into the subthalamic nucleus (STN) with the methods we have developed (1). Of these patients, 19 received bilateral electrodes in a single surgical setting, 5 received bilateral electrodes in two separate procedures, and 5 received unilateral electrodes. All patients signed an informed consent form that was approved by the university's committee on human research. Our targeting error was evaluated as the distance between the intended and actual electrode location (Figure 1) on the scan plan in which the target was identified (radial error) and the distance between the intended and actual coordinates of the electrode tip with respect to the anterior and posterior commissures (AC-PC) of the brain (tip error).

We compare our MR guided results to control data obtained using standard frame-based stereotaxy at our institution (2). This study reported on 44 comparable PD patients in which 76 DBS electrodes were implanted. We compared the mean electrode tip errors with unpaired t-tests and further evaluated potential correlations with an assortment of factors including: case order, patient age, side of surgery, sagittal plane trajectory angle, and coronal plane trajectory angle. Statistical significance was taken as p less than 0.05.

Results

Mean targeting errors in the axial plane in which the STN target was identified were 1.18 ± 0.65 mm for MR guided implantations. The electrode tip error (in mm) was broken down into individual components and is presented in Table 1. The errors were statistically smaller for MR guided implantations than for stereotactic methods for the X and Y directions and cumulative vector, while the Z (depth) error was not significantly different. Mean absolute errors (absolute value of the difference between intended and actual tip position) produced comparable results, with MR significantly better in X, Y and cumulative error. For MR procedures we evaluated potential predictors of electrode placement accuracy. The only statistically significant predictor of error was found to be coronal approach angle, which correlated with increasing absolute lateral error ($r=0.4$, $p=0.03$).

Table 1: Comparison of electrode tip errors

Group	X error	Y error	Z error	Vector
MR guided	-0.07 ± 0.96	0.25 ± 1.10	1.36 ± 1.27	2.18 ± 0.92
Standard	-0.76 ± 1.48	0.57 ± 1.73	0.86 ± 2.14	3.06 ± 1.41

Conclusions

MR guided placement of DBS electrodes is capable of producing excellent targeting accuracy. This accuracy is shown to be statistically superior to that achieved with conventional stereotactic placement. Correlation analysis of MR guided implantations revealed a tendency for increased lateral errors when higher coronal angle trajectories were employed.

References

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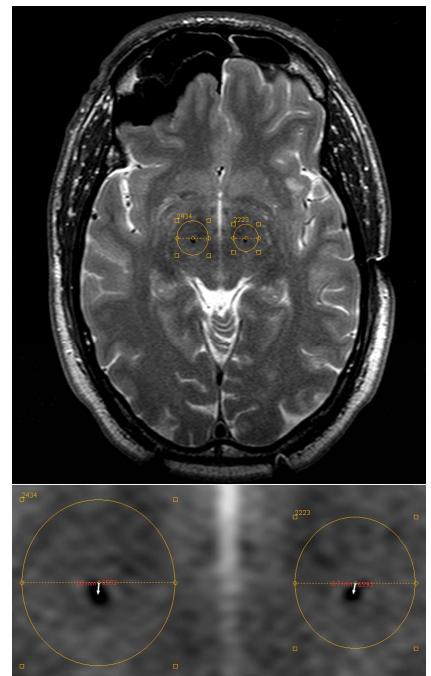


Figure 1 – An axial scan plane 4 mm below AC-PC where the targets within the STN were established. This post-implantation scan shows the intended target (center of orange circle) and actual location (small signal void). The lower panel shows a magnified view of these targets and the radial error (white arrows) between intended and actual position.