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Frameless deep brain stimulation surgery: A community hospital experience

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ABSTRACT

Objective: Frame-based stereotaxy has regularly been utilized for deep brain stimulation (DBS) surgery. More recently, frameless neuronavigation has revealed similar outcomes for functional neurosurgical operations. Such comparable outcomes have been described by tertiary referral centers, but whether such excellent surgical outcomes are attainable in a community setting has yet to be reported.
Methods: Eighteen patients received frameless DBS surgery, 11 with subthalmic nucleus (STN) implantation for Parkinson's disease (PD) and 7 with ventral intermediate nucleus (Vim) implantation for essential tremor (ET). Their data was collected and analyzed, including the Unified Parkinson's Disease Rating Scale (UPDRS) and tremor scores.
Results: There was a 58% reduction in UPDRS III and a 47% reduction in overall levodopa dose in those with STN DBS ($p < 0.0001$ and $p < 0.0005$, respectively) and those with Vim DBS had a 76% improvement in their overall tremor rating score ($p < 0.002$) at mean follow-up (8.2 and 10.1 months, respectively). No intraoperative complications occurred. Two subjects developed wound dehiscence post-operatively and another had fall-induced lead fracture, all treated with uncomplicated hardware replacement.
Conclusions: Frameless DBS for PD and ET can be safely performed in a community setting with similar excellent outcomes as those of larger academic centers as well as clinical results comparable to frame-based surgery. Patients living in community or rural areas may not need to travel across city or even state lines to receive this surgical option, especially if they have the opportunity to receive it closer to home.

1. Introduction

Deep brain stimulation (DBS) surgery has been widely used for treating the disabling symptoms of Parkinson's disease (PD) in its advanced stages and essential tremor (ET) refractory to medical therapy [1,2]. While its exact mechanism of action is not quite clear, DBS alters neuronal activity via a small current that is sent deep into regions of the brain motor nuclei at high frequency [2,3]. Multiple large studies have demonstrated the effectiveness of DBS in ameliorating the disabling symptoms of PD by decreasing motor fluctuations and dyskinesia and others have shown its drastic benefit for ET [4,5]. Traditionally, frame-based stereotactic methods have dependably been utilized to accurately guide electrodes that target specific deep brain structures. However, stereotactic frames have limitations for both the surgical team and the patient alike. Previous studies noted impediments such as an extended procedure time, potential obstacles in surveillance of the patient's motor and verbal responses throughout the operation and particularly during stimulation, and the strain of the heavy and restrictive frame on the patient during the lengthy operation [6–8]. In spite of these hurdles, functional neurosurgical procedures are primarily carried out via a stereotactic frame [8,9]. Nonetheless, previous reports and studies have demonstrated the efficacy of frameless DBS (with reported p-values of <0.01) and others have shown that its outcomes can be just as efficacious as frame-based interventions [6–8,10,11]. In this study, we report our experience with frameless DBS as further evidence for its beneficial use as well as its comparable performance in a community setting.

To date, only a few studies have reported outcomes of frameless DBS and they are primarily from tertiary academic referral centers [7,8,11]. Accordingly, we sought to assess our community hospital-based experience with frameless DBS. Here, we describe our experience with frameless DBS surgery and compare our outcomes with previous studies as well as the frame-based approach.

2. Materials and methods

2.1. Patients

A total of 18 patients received frameless DBS at the New Jersey Neuroscience Institute between January 2009 and December 2010. Their data was collected from a computerized medical record,

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Table 1
Characteristics of patients undergoing STN stimulation (*N* = 11).

Characteristics	
Age (years)	
Range	48–80
Mean ± SD	66.1 ± 10.4
Sex	
Males	8
Females	3
Duration of PD (years)	
Range	4–21
Mean ± SD	10.6 ± 4.5
Levodopa dose[a] (mg/day)	
Range	750–1850
Mean ± SD	1233.6 ± 338.5
Side of STN stimulation	
Bilateral	8
Right	1
Left	2

[a] Levodopa equivalent dose, calculated using these accepted equivalents: 100 mg Levodopa = 125 mg controlled-release levodopa = 1 mg pergolide = 1.5 mg pramipexole [8].

including outpatient notes, inpatient notes, and operative reports. Eleven patients received either bilateral or unilateral subthalmic nucleus (STN) stimulation for symptoms of PD and 7 patients received either bilateral or unilateral ventral intermediate nucleus (Vim) stimulation for tremor due to ET, PD or multiple sclerosis. The consideration criteria for STN DBS were development of disabling Parkinsonian motor response complications such as dyskinesias, on–off phenomena, and fluctuating response to medication and those for Vim DBS were severe tremor refractory to medical therapy and causing serious interference in activities of daily living. Neuropsychological evaluation was performed on every patient to ensure appropriateness for surgery. Profiles of the patients are summarized in Tables 1 and 2.

2.2. Surgery

Surgery was performed with the Waypoint™ Stereotactic System (FHC, Inc., Bowdoin, Maine), which utilized the microTargeting™ STar™ Drive System and the microTargeting™ Platform mount for targeting. Fig. 1 shows the STN targeting plan using this system and a virtual image the Platform mount. Prior to surgery, comprehensive magnetic resonance imaging (MRI) of the brain was obtained to facilitate surgical approach and to evaluate the presence of any intracranial lesions. Additionally, following placement of bone fiducial markers to the skull, a head computed tomography (CT) scan was obtained and images were loaded into the Waypoint™ treatment planning system and were combined with the MRI images to target the STN or Vim. An atlas-based system was used to target these nuclei [12]. The STN was targeted 10–12 mm lateral to the anterior commissure–posterior commissure (AC–PC) line, 0 to −3 mm vertical to the AC–PC plane, and 2–3 mm posterior to the midpoint of AC–PC and Vim was targeted 11 mm lateral from third ventricle wall, 0 mm vertical to the AC–PC plane, and 6 mm anterior to the PC. Final targeting of the nuclei and delivery of the quadrupolar DBS electrode was fine-tuned via microelectrode recording (MER) in a similar fashion as discussed by D'Haese et al. [12]. MER was used in all cases, with somatopic mapping when possible, and targeting was determined both from intraoperative recording of cell activity and response to microstimulation. We also checked for stimulation-induced side effects with both micro- and macro-stimulation to help determine optimal electrode position. Finally, a post-operative CT scan was obtained to validate lead location and to assess the presence of hemorrhage.

Table 2
Characteristics of patients undergoing Vim stimulation (*N* = 7).

Characteristics	
Age (years)	
Range	45–79
Mean ± SD	66.6 ± 10.6
Sex	
Males	4
Females	3
Duration of tremor (years)	
Range	4–20
Mean ± SD	12.6 ± 6.6
Cause of tremor	
ET	3
PD	3
MS	1
Side of Vim stimulation	
Bilateral	4
Right	1
Left	2

PD: Parkison's disease; ET: essential tremor; MS: multiple sclerosis.

2.3. Follow-up

Testing and DBS electrode programming was performed 1 week after surgery and patient follow-ups took place every 1–2 months for the first 6 months and every 3–4 months thereafter. For PD patients, testing was carried out in the off-medication and on-DBS condition and assessment was carried out via the Unified Parkinson's Disease Rating Scale (UPDRS). Those with tremor were evaluated using a tremor assessment scale that is based on the Clinical Rating Scale for Tremor [13], which quantified the combination of the subject's own rating (which includes interruption in working, dressing, drinking, hygiene, etc.), physician's rating of resting, postural, kinetic/action, head/neck, and voice tremor as well as line and spiral drawing. At each follow-up, stimulation parameters were adjusted to achieve optimal symptom relief and diminish side effects.

2.4. Statistical analysis

Data collected included patient's age, sex, levodopa dosage, UPDRS-II and -III scores, and tremor scores. Pre- and postoperative data were compared statistically. Statistical analyses were performed on the clinical rating scores and the levodopa dosage pre- and post-DBS. Outcomes were compared using a paired *t*-test. In the analysis, an assumption of normality was made and confirmed by the normal probability plot.

3. Results

A total of 18 patients underwent frameless DBS surgery with 12 undergoing bilateral electrode implantation for a total of 30 implanted electrodes. Eleven patients received STN implantation, with 8 receiving bilateral implants. Seven patients received Vim implantation, with 4 receiving bilateral implants. Mean follow-up for the STN patients was 8.2 ± 3.0 months and for Vim patients it was 10.1 ± 4.3 months.

3.1. Patients with STN implantation

Patients that underwent STN implantation had a mean age of 66.1 ± 10.4 years with 8 males and 3 females. The mean duration of PD symptoms prior to STN implantation was 10.6 ± 4.5 years. There were no intraoperative complications. One patient developed lead fracture post-operatively that required removal and subsequent replacement. The UPDRS II (activities of daily living) and III (motor) scores and subscores pre- and post-operatively