Deep Brain Stimulation (DBS) is an effective therapy for advanced movement disorders, and patient selection is one of the most important factors in determining postoperative benefit. There is evidence that more than 30% of patients who were considered DBS failures were actually poor candidates for DBS, suggesting significant variation in physicians’ understanding of surgical indications. In addition to referral of inappropriate candidates for DBS, a poor understanding of surgical indications may prevent referral of many patients who would significantly benefit from DBS. As the indications for DBS broaden to include other neurological and psychiatric conditions, the need to ensure adequate knowledge of surgical candidacy for DBS will become more crucial.

To our knowledge, a single study has analyzed the appropriateness of referrals made to a DBS center. This research found that only 4.5% of referrals were good DBS candidates. Because these results were published just 2 years after DBS was approved by the Food and Drug Administration to treat advanced idiopathic Parkinson disease (IPD), the low percentage of appropriate referrals may have reflected uncertainties about patient selection owing to the novelty of the procedure. We hypothesize that physicians’ understanding of selection criteria for DBS has improved over the ensuing years. To investigate the current level of knowledge surrounding DBS candidacy, we reviewed the most recent referral patterns to a large tertiary movement disorders center with an active DBS program.

METHODS

PATIENT POPULATION

We reviewed the medical records of all patients referred to the Movement Disorders Center at The Mount Sinai Medical Center be-
between December 1, 2005, and November 30, 2009. All medical Current Procedural Terminology initial visit codes 99201-05 and initial consultation codes 99241-45 were selected. The initial note for the first visit was then reviewed to identify patients who were referred for DBS. The Institutional Review Board of The Mount Sinai Medical Center approved this retrospective medical record review.

CATEGORIES

Patients were categorized as those who were self-referred and those who were referred by a physician. The physician-referred group was further subdivided according to the type of physician who made the referral. General neurologists, primary medical physicians, and other physicians (neurosurgeons, psychiatrists, neuropsychologists, and ophthalmologists) were grouped into the category of non—movement disorder physicians. Referral patterns of these physicians were analyzed separately from those of movement disorder specialists.

Using generally accepted criteria,3,6,7 each patient was classified as to whether he or she was an appropriate candidate for DBS. These criteria included the following: (1) a diagnosis of medically refractory IPD, primary generalized dystonia, or essential tremor (ET), with symptoms that substantially interfere with the patient’s quality of life and functionality, (2) intact cognition, (3) the absence of an untreated or disabling psychiatric illness, (4) realistic expectations, (5) the ability and willingness to participate in regular follow-up visits, and (6) the absence of comorbidities that are contraindications to DBS. Specific diagnostic criteria for IPD and atypical parkinsonian syndromes were established using widely recognized consensus statements.8,9

Additional surgical criteria for patients with IPD included the following: (1) symptom duration for 5 years or longer, (2) a documented positive response to levodopa therapy, (3) a history of on-off fluctuations requiring frequent levodopa dosing, (4) marked disability in the off-medication state, and (5) severe dyskinesias or tremor. A levodopa challenge test was used to confirm response to levodopa therapy. Patients with primary dystonia were considered DBS candidates if they met the general criteria aforesaid and if they were refractory to an adequate trial of accepted oral medications, including anticholinergics, baclofen, and benzodiazepines, with or without botulinum toxin injections. Patients with secondary dystonia were considered poor candidates, as DBS is less effective in these patients and the Food and Drug Administration has not approved DBS for the treatment of secondary dystonia. Patients with ET were considered good DBS candidates if they met the general criteria aforesaid and if they were refractory to an adequate trial of accepted oral medications, including β-blockers and primidone.

Referrals for DBS were categorized into 1 of the following 4 groups: (1) good candidates, (2) possible future candidates, (3) poor candidates because of neurological contraindications, and (4) poor candidates because of medical contraindications. Patients were considered possible future candidates if they had mild symptoms that were controlled by medications, had a nonoptimized medication regimen, had an unstable yet treatable psychiatric disease, or had IPD for less than 5 years. Medication optimization in IPD was based on published algorithms.5 In particular, patients were considered to have had an adequate medication trial if all the following were documented: (1) a benefit using levodopa, (2) a levodopa formulation at least 4 times per day, (3) a levodopa formulation plus a dopamine agonist (or medication equivalent), and (4) a levodopa formulation plus a levodopa extender (ie, monoamine oxidase inhibitors or catechol-O-methyltransferase inhibitors).

Neurological contraindications to DBS included dementia, secondary dystonia, atypical parkinsonism, a refractory psychiatric disease, a psychogenic movement disorder, brain parenchyma lesions that suggest a secondary pathologic condition, and predominant parkinsonian symptoms that are unresponsive to subthalamic or pallidal DBS. These calculations were determined for the aggregate period and for 1-year intervals.

STATISTICAL ANALYSIS

Collected data were analyzed using commercially available statistical software (SPSS version 18; SPSS, Inc, Chicago, Ill). Analysis of variance was used to test for any significant differences between the means of more than 2 groups. Significant differences between any 2 groups were then confirmed using a post hoc independent samples t test. P < .05 was considered statistically significant. χ² Test was used to analyze categorical responses between 2 independent groups.

RESULTS

We reviewed medical records of 612 patients who were referred to the Movement Disorders Center at The Mount Sinai Medical Center between December 1, 2005, and November 30, 2009. Among these, 197 patients (32.2%) were specifically referred for DBS evaluation. In total, 415 medical records were excluded, 396 because the patients were not referred for DBS evaluation and 19 because of insufficient data. Of 197 patients, 129 (65.5%) had an initial diagnosis of IPD, 6 (3.0%) had ET, 60 (30.5%) had primary dystonia, and 2 (1.0%) had other pathologic tremors (Table 1). The mean (SD) ages were 65 (9) years for patients with IPD, 66 (15) years for patients with ET, and 35 (21) years for patients with primary dystonia (Table 2).

In total, 165 referrals (83.8%) had ailments for which DBS was indicated. Eighteen patients with an initial diagnosis of IPD seemed to be misdiagnosed. The corrected diagnoses included 7 patients with multiple system atrophy, 4 patients with vascular parkinsonism, 3 patients with corticobasal degeneration, 2 patients with ET, 1 patient with primary gait disorder, and 1 patient with psychogenic movement disorder. Two patients with an initial diagnosis of ET were misdiagnosed; one patient had tremor associated with IPD, and the other patient had tremor secondary to dystonia. Finally, 2 patients with an initial diagnosis of generalized non-DYT1 dystonia were misdiagnosed. The corrected diagnoses included 1 patient with a complex tic disorder and 1 patient with focal cervical dystonia. An analysis of 60 patients with confirmed diagnoses of dystonia revealed that 47 patients had primary dystonia and 13 patients had secondary dystonia. Table 1 lists the corrected diagnoses of all the patients studied.

Among 197 patients referred for DBS with complete data, 100 (50.8%) were good candidates (62 with IPD, 35 with dystonia, and 3 with ET), 50 (25.4%) were possible future candidates, 44 (22.3%) were poor candidates because of neurological contraindications, and 3 (1.5%) were poor candidates because of medical contraindications. Among 112 DBS referrals with IPD, 62 (55.4%) were good candidates, 39 (34.8%) were pos-
significant in their percentages of good candidates, and 1 with untreated psychiatric disease), and 11 (9.8%) were poor DBS candidates (9 with dementia and 2 with symptoms unresponsive to DBS). Among 60 DBS referrals with dystonia, 35 (58.3%) were good candidates, 10 (16.7%) were possible future candidates (because of insufficient medication trial), 14 (23.3%) were poor candidates because of neurological contraindications (13 with secondary dystonia and 1 with a psychogenic movement disorder), and 1 patient (1.7%) was a poor candidate because of medical contraindications. Finally, among 6 DBS referrals with ET, 3 were good candidates, 1 was a possible future candidate (because of insufficient medical management), and 2 were poor candidates because of medical contraindications.

Data identifying referral sources were available for 179 of 197 patients (90.9%). Among 104 patients self-referred or referred by non–movement disorder physicians, 42 (40.4%) were good candidates, 34 (32.7%) were possible future candidates, 26 (25.0%) were poor candidates because of neurological contraindications, and 2 (1.9%) were poor candidates because of medical contraindications (Table 3). Movement disorder specialists referred 75 patients for DBS, of whom 50 (66.7%) were good candidates, 11 (14.7%) were possible future candidates, and 14 (18.7%) were poor candidates because of neurological contraindications. Referrals by movement disorder specialists vs other sources differed significantly in their percentages of good candidates (66.7% vs 40.4%; χ²=12.36, P=.002) and possible future candidates (14.7% vs 32.7%; χ²=7.54, P=.02) but not poor candidates (18.7% vs 25.0%; χ²=1.01, P=.60). Table 4 summarizes the good, possible future, and poor candidates referred by movement disorder specialists vs other sources.

More possible future candidates were referred by primary medical physicians (33.3%) than by movement disorder specialists (14.7%) (P=.01). None of the differences among other physicians were significant. All the possible future candidates referred by primary medical physicians did not have their medications optimized compared with 72.8% of those referred by movement referred patients (26.3%), although differences in referral patterns for poor candidates were not statistically significant (F=0.45, P=.77).

During 4 years of non–movement disorder physician referrals and self-referred patients, we observed a decrease in good candidates and an increase in poor candidates, but none of these trends were statistically significant (Figure). A year-by-year analysis of referrals by movement disorder specialists revealed a significant decrease in good candidates over time (F=4.33, P=.007), which remained significant even when patients with secondary dystonia were excluded (F=3.68 P=.02). Correspondent increases in possible future candidates and in poor candidates were not statistically significant.

Referral quality was also analyzed based on disease diagnosis. Among patients with confirmed IPD, there was no significant difference in percentages of patients referred by movement disorder specialists (85.1%) vs other sources (84.3%), with 55.4% of patients having IPD in our study sample considered good candidates. Movement disorder specialists vs other sources referred significantly more good candidates with IPD (70.0% vs 48.3%; χ²=4.60, P=.03) and significantly fewer possible future candidates with IPD (22.5% vs 45.0%; χ²=5.27.

### Table 1. Presumed and Corrected Diagnoses of 197 Patients Referred for Deep Brain Stimulation

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Presumed Diagnosis, No. (%)</th>
<th>Incorrectly Diagnosed Patients, No.</th>
<th>Corrected Diagnosis, No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idiopathic Parkinson disease</td>
<td>129 (65.5)</td>
<td>18</td>
<td>112 (56.9)</td>
</tr>
<tr>
<td>Atypical Parkinson disease</td>
<td>0</td>
<td>0</td>
<td>15 (7.6)</td>
</tr>
<tr>
<td>Essential tremor</td>
<td>6 (3.0)</td>
<td>2</td>
<td>6 (3.0)</td>
</tr>
<tr>
<td>Dystonia a</td>
<td>60 (30.5)</td>
<td>2</td>
<td>60 (30.5)</td>
</tr>
<tr>
<td>Other pathologic tremor b</td>
<td>2 (1.0)</td>
<td>0</td>
<td>2 (1.0)</td>
</tr>
<tr>
<td>Psychogenic movement disorder</td>
<td>0</td>
<td>0</td>
<td>1 (0.5)</td>
</tr>
<tr>
<td>Other c</td>
<td>0</td>
<td>0</td>
<td>1 (0.5)</td>
</tr>
</tbody>
</table>

a Includes 47 patients with primary dystonia and 13 patients with secondary dystonia.

b Includes paraneoplastic cerebellar degeneration and tremor secondary to brain tumor.

c Includes complex tic disorder.

### Table 2. Demographics of 165 Patients Properly Referred for Deep Brain Stimulation

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Idiopathic Parkinson Disease (n = 112)</th>
<th>Essential Tremor (n = 6)</th>
<th>Primary Dystonia (n = 47)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>65 (9)</td>
<td>66 (15)</td>
<td>35 (21)</td>
</tr>
<tr>
<td>Female sex, No. (%)</td>
<td>33 (30.0)</td>
<td>2 (33.3)</td>
<td>21 (44.7)</td>
</tr>
<tr>
<td>Race/ethnicity, No. (%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>White</td>
<td>55 (49.1)</td>
<td>4 (66.7)</td>
<td>31 (66.0)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>4 (3.6)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Asian</td>
<td>2 (1.8)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>4 (3.6)</td>
<td>0</td>
<td>1 (2.1)</td>
</tr>
<tr>
<td>Missing</td>
<td>47 (41.9)</td>
<td>2 (33.3)</td>
<td>15 (31.9)</td>
</tr>
<tr>
<td>Duration of illness, mean (SD), mo</td>
<td>150 (80)</td>
<td>244 (130)</td>
<td>220 (201)</td>
</tr>
</tbody>
</table>

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Among patients with confirmed primary dystonia, there was no significant difference in percentages of patients referred by movement disorder specialists (95.5%) vs other sources (94.7%), with 74.5% of patients having primary dystonia considered good candidates. Movement disorder specialists vs other sources referred significantly more good candidates with primary dystonia (90.9% vs 63.2%; \( \chi^2 = 4.58, P = .03 \)). There was no significant difference in their referral of possible future candidates or poor candidates with primary dystonia. Patients with ET were excluded from this analysis because of the small sample with this diagnosis in the reviewed study population.

P = .02); their numbers of poor candidates with IPD were essentially the same (7.5% vs 6.7%).

Among patients with confirmed primary dystonia, there was no significant difference in percentages of patients referred by movement disorder specialists (95.5%) vs other sources (94.7%), with 74.5% of patients having primary dystonia considered good candidates. Movement disorder specialists vs other sources referred significantly more good candidates with primary dystonia (90.9% vs 63.2%; \( \chi^2 = 4.58, P = .03 \)). There was no significant difference in their referral of possible future candidates or poor candidates with primary dystonia. Patients with ET were excluded from this analysis because of the small sample with this diagnosis in the reviewed study population.
cally. More referrals from primary medical physicians and self-referred patients were poor candidates, although none of the patterns of poor candidate referrals were statistically significant.

In a year-by-year analysis of the study period, the significant decrease in referral of good candidates over time and the concurrent increases in referral of possible future candidates and poor candidates may be attributed to several factors. It is intriguing to speculate that physicians may have become more eager as they became more comfortable with DBS to refer patients with secondary dystonia for surgical evaluation or patients with IPD earlier in their disease progression. Notably, this trend remained significant even after excluding patients with secondary dystonia from the analysis. Although it is important for physicians and the general public to be aware of the data presented herein, they should not be overly cautious when making referrals to a DBS center, which may delay or prevent appropriate candidates from being considered for this modality.3

Limitations of this study include its retrospective design and small sample size, as well as possible sampling bias owing to the fact that the study was performed in a single academic metropolitan tertiary care center. This may limit the generalizability of the results. In addition, some restrictive criteria used to define DBS candidates, such as considering secondary dystonia a poor surgical indication, may have artificially decreased the number of good candidates and increased the number of poor candidates. On the other hand, we chose not to consider advanced age as a limiting factor for DBS eligibility because there is no good evidence supporting a definite age cutoff.6 This may have artificially increased the number of good candidates compared with a surgical program using a stricter age cutoff.

In conclusion, we found a marked improvement in referral quality for DBS compared with prior investigations. Our study findings—which include the first published comprehensive analysis of referral patterns among patients with IPD, ET, and primary dystonia—may guide future educational efforts about DBS candidacy. Further prospective studies, possibly including a larger sample size and a multicenter design, will be needed to monitor whether continued improvement in referral practices for surgical management of movement disorders is sustainable over time.

Accepted for Publication: April 5, 2011. 
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Author Contributions: Drs Katz and Tagliati had full access to all the data in the study and take responsibility

Figure. Year-to-year trends in the quality of deep brain stimulation referrals over 4 years of observation by movement disorder specialists (A, C, and E) and by non–movement disorder physicians or self-referred patients (B, D, and F).
for the integrity of the data and the accuracy of the data analysis. Study concept and design: Katz, Kilbane, and Tagliati. Acquisition of data: Katz, Kilbane, Rosengard, and Tagliati. Analysis and interpretation of data: Katz, Alterman, and Tagliati. Drafting of the manuscript: Katz, Kilbane, and Tagliati. Critical revision of the manuscript for important intellectual content: Katz, Rosengard, Alterman, and Tagliati. Statistical analysis: Katz. Administrative, technical, and material support: Rosengard and Alterman. Study supervision: Tagliati.

Financial Disclosure: Dr Alterman has received teaching honoraria and consulting fees from Medtronic Inc. Dr Tagliati has received teaching honoraria from Medtronic Inc, Allergan, Boehringer Ingelheim, Glaxo, and Novartis and consulting fees from St Jude/Advanced Neuromodulation System, Inc, all of which were unrelated to the conduct of this study.

Previous Presentations: This study was presented at the Annual Meeting of the American Academy of Neurology; April 11, 2011; Honolulu, Hawaii; and at the 15th International Congress of Parkinson’s Disease and Movement Disorders of the Movement Disorder Society; June 6, 2011; Toronto, Ontario, Canada.

REFERENCES