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Efficacy and Safety of Deep Brain Stimulation in Tourette Syndrome

The International Tourette Syndrome Deep Brain Stimulation Public Database and Registry

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IMPORTANCE Collective evidence has strongly suggested that deep brain stimulation (DBS) is a promising therapy for Tourette syndrome.

OBJECTIVE To assess the efficacy and safety of DBS in a multinational cohort of patients with Tourette syndrome.

DESIGN, SETTING, AND PARTICIPANTS The prospective International Deep Brain Stimulation Database and Registry included 185 patients with medically refractory Tourette syndrome who underwent DBS implantation from January 1, 2012, to December 31, 2016, at 31 institutions in 10 countries worldwide.

EXPOSURES Patients with medically refractory symptoms received DBS implantation in the centromedian thalamic region (93 of 163 [57.1%]), the anterior globus pallidus internus (41 of 163 [25.2%]), the posterior globus pallidus internus (25 of 163 [15.3%]), and the anterior limb of the internal capsule (4 of 163 [2.5%]).

MAIN OUTCOMES AND MEASURES Scores on the Yale Global Tic Severity Scale and adverse events.

RESULTS The International Deep Brain Stimulation Database and Registry enrolled 185 patients (of 171 with available data, 37 females and 134 males; mean [SD] age at surgery, 29.1 [10.8] years [range, 13-58 years]). Symptoms of obsessive-compulsive disorder were present in 97 of 151 patients (64.2%) and 32 of 148 (21.6%) had a history of self-injurious behavior. The mean (SD) total Yale Global Tic Severity Scale score improved from 75.01 (18.36) at baseline to 41.19 (20.00) at 1 year after DBS implantation ($P < .001$). The mean (SD) motor tic subscore improved from 21.00 (3.72) at baseline to 12.91 (5.78) after 1 year ($P < .001$), and the mean (SD) phonic tic subscore improved from 16.82 (6.56) at baseline to 9.63 (6.99) at 1 year ($P < .001$). The overall adverse event rate was 35.4% (56 of 158 patients), with intracranial hemorrhage occurring in 2 patients (1.3%), infection in 4 patients with 5 events (3.2%), and lead explantation in 1 patient (0.6%). The most common stimulation-induced adverse effects were dysarthria (10 [6.3%]) and paresthesia (13 [8.2%]).

CONCLUSIONS AND RELEVANCE Deep brain stimulation was associated with symptomatic improvement in patients with Tourette syndrome but also with important adverse events. A publicly available website on outcomes of DBS in patients with Tourette syndrome has been provided.

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Video

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Surgical therapies for Tourette syndrome have been used since the early 1960s. Ablative procedures were initially used to target specific areas of the brain; these approaches revealed inconsistent, but in many cases reasonably positive, clinical outcomes, particularly on motor tics. Ablative surgical procedures did not become mainstream and largely disappeared from the treatment arsenal for Tourette syndrome.[1] Deep brain stimulation (DBS) for Tourette syndrome, introduced in 1999,[2] is a surgical therapy that uses an implantable device to deliver electrical stimulation to specific and carefully targeted brain structures. Deep brain stimulation is approved by the US Food and Drug Administration and Conformité Européene Mark approved in the European Union for the treatment of selected cases of Parkinson disease and essential tremor. Deep brain stimulation has a Conformité Européene Mark for selected cases of primary and secondary dystonia.[3] Deep brain stimulation also received approval from the US Food and Drug Administration under a humanitarian device exemption for dystonia and obsessive-compulsive disorder.[4] Although DBS is not approved for Tourette syndrome in the United States and other countries, multiple single reports and case series have collectively demonstrated that DBS could be a potentially valuable therapy for select cases of severe medication-resistant Tourette syndrome. A recent systematic review and meta-analysis of 57 studies including 156 cases of DBS for Tourette syndrome reported an overall improvement of 53% as measured by the total Yale Global Tic Severity Scale (YGTSS) score.[5]

Although DBS is a promising therapy for Tourette syndrome, critical questions remain unanswered. In addition, insurance reimbursement for the procedure is not consistently provided (eg, in the United States). Issues that remain unresolved include selection of appropriate candidates, age, brain target for individual symptoms, and optimal stimulation parameters, as well as immediate and delayed postoperative complications. In addition, it is unresolved if DBS will play a role beyond treating motor and vocal tics. In an effort to address these questions, an international multicountry study organized by the Tourette Association of America was undertaken. The International Deep Brain Stimulation Database and Registry was launched in 2012 (https://tourettedeepbrainstimulationregistry.ese.ufhealth.org/).[6] The main rationale driving its creation was the reality that even expert centers will perform only a small number of DBS procedures for Tourette syndrome, and thus there existed a critical need for data. These multicountry pooled data would be used in an effort to influence and improve DBS outcomes. The project aimed to combine outcome information from a variety of centers worldwide and to create a publicly available website to share data. This report describes the Tourette syndrome DBS cohort inclusive of 1-year outcome data.

Key Points

Question What are the outcomes associated with deep brain stimulation in Tourette syndrome?

Findings In this study including 185 patients from 10 countries in the International Deep Brain Stimulation Database and Registry, the mean Yale Global Tic Severity Scale score improved 45.1% at 1 year after deep brain stimulation implantation. The centromedian thalamic region was the most common target of deep brain stimulation implantation (57.1%), with no differences observed between targets, while the most common adverse events were dysarthria (6.3%) and paresthesias (8.2%), with hemorrhages occurring in 1.3% of patients, infection in 3.2%, and explantation in 0.6%.

Meaning Deep brain stimulation was safe and associated with clinical improvements; a publicly available website has been released that tracks the outcomes among all participating centers.

Methods

This study includes data from the International Deep Brain Stimulation Database and Registry from January 1, 2012, to December 31, 2016. Information on 185 patients with bilateral Tourette syndrome DBS was drawn from 31 different institutions across Australia (17 [9.2%]), Europe (78 [42.2%]), Asia (35 [18.9%]), and North America (55 [29.7%]). Participants were selected for surgery based on local evaluations according to current recommendations. All patients included in the registry and database were used for the analysis. There was no standardization of screening for inclusion criteria.[7,8] A recent article about the registry and database detailed the procedures and instruments used.[6] The documented variables included sex; age at onset, diagnosis, and surgery; associated comorbidities; preoperative and follow-up clinical scales at 6 and 12 months; characteristics of the surgical procedure including brain target, targeting procedure, lead location, and DBS programming parameters; and surgical and postsurgical adverse events. The YGTSS was used to measure clinical outcomes.[9] The study was approved by the University of Florida Institutional Review Board and written informed consent was obtained from the participants according to each participating institution's procedures.

Statistical Analysis

All analyses were performed using SPSS, version 23 (SPSS Inc). Data were largely normally distributed, with skewness and kurtosis values consistently between -1 and +1 for all YGTSS outcome data, with the exception of the month 24 data, which showed the total YGTSS score as slightly positively skewed (1.14) and leptokurtic (1.36). Owing to these violations of normality and the small sample size available at month 24 follow-up, outcomes were only formally analyzed for up to a 1-year interval. Sphericity and error variances were examined prior to interpreting the results. When significant violations were observed, the Greenhouse-Geisser adjustment was applied as appropriate and *df* appropriately adjusted. Bonferroni corrections were applied in all post hoc analyses. When interpreting the data, it was noted that the YGTSS scores were inversely associated with disease-related symptoms, such that the higher the score, the more severe the symptoms.

Missing data were eliminated casewise, such that participants who were missing any data point in the model were excluded, as is standard in SPSS. Because this analysis included people who had follow-ups at 6 and 12 months, it eliminated

those who had only 1 follow-up, but not both. This decision to include both 6- and 12-month data was made to provide the most meaningful interpretation of results, weighing the number of participants lost to follow-up. In addition, because each site varied on the data points collected, the numbers varied based on the variables analyzed. Although there were 185 individuals in the data set, not every site collected each data point on their participants depending on their standard assessment procedure. For the total YGTSS score, we had complete data for 89 participants, and for the motor tic and phonic tic subscores, we had complete data for 40 participants each. A post hoc power analysis in G-Power (Franz Faul, University of Kiel) showed that adequate power was achieved to detect a moderate effect size for all scales.

First, YGTSS motor tic scores were examined using repeated-measures analysis of variance, with time point (baseline, 6-month follow-up, and 12-month follow-up) as the within-participants factor, and stimulation target as the between-participants factor. The effect of time and DBS target on motor symptoms was analyzed, as well as whether the effect was similar across targets (time × target interactions). Using the same method that was used with the motor tic scores, YGTSS phonic tic scores were examined using repeated-measures analysis of variance, with time point (baseline, 6-month follow-up, and 12-month follow-up) as the within-participants factor and target as the between-participants factor. Finally, the same analytical method was applied to YGTSS total scores (sum of motor tic, phonic tic, and impairment subscales of YGTSS): repeated-measures analysis of variance, with time point (baseline, 6-month follow-up, and 12-month follow-up) as the within-participants factor and target as the between-participants factor. Patients whose implant was placed in the anterior limb of the internal capsule (ALIC) were excluded from between-group comparisons owing to the small sample size. Means and descriptive statistics were used for stimulation settings and adverse effects. $P < .05$ (2-sided) was considered significant.

Results

To date, the International Deep Brain Stimulation Database and Registry includes 185 patients from 10 countries. **Table 1** describes the cohort's characteristics. A total of 134 of 171 participants with available data were male (78.4%), with a mean (SD) age of symptom onset of 7.8 (3.5) years. The mean (SD) age at diagnosis was 12.3 (7.2) years and mean (SD) age at surgery was 29.1 (10.8) years. The 2 most common comorbidities were obsessive-compulsive disorder (97 of 151 [64.2%]) and depression (70 of 148 [47.3%]). A total of 43 of 152 participants (28.3%) met criteria for attention-deficit/hyperactivity disorder. Self-injurious behavior was reported in 32 of 148 patients (21.6%). The most commonly targeted brain structure was the centromedian thalamic region (93 of 163 [57.1%]) (**Figure**).

Table 1. Baseline Values in the Multinational Tourette Syndrome DBS Cohort

Characteristic	Patients, No./ Total No. (%)
Sex	
Male	134/171 (78.4)
Female	37/171 (21.6)
Age, mean (SD), y	
Onset (n = 138)	7.8 (3.5)
Diagnosis (n = 116)	12.3 (7.2)
Surgery (n = 173)	29.1 (10.8)
Comorbidities	
OCD	97/151 (64.2)
Depression	70/148 (47.3)
Anxiety	53/148 (35.8)
ADHD	43/152 (28.3)
Self-injurious behavior	32/148 (21.6)
Target	
Centromedian thalamic region	93/163 (57.1)
Anterior globus pallidus internus	41/163 (25.2)
Posterior globus pallidus internus	25/163 (15.3)
Anterior limb of internal capsule	4/163 (2.5)

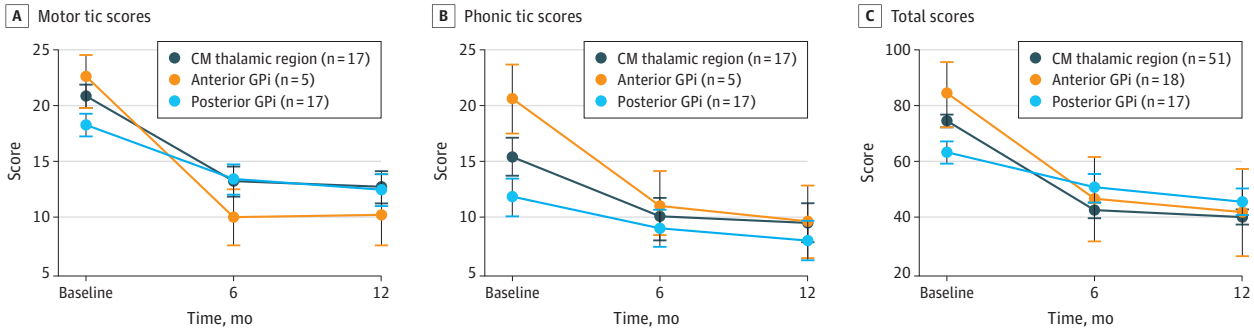
Abbreviations: ADHD, attention-deficit/hyperactivity disorder; DBS, deep brain stimulation; OCD, obsessive-compulsive disorder.

YGTSS Motor Tic and Phonic Tic Scores

Table 2 summarizes the baseline YGTSS scores as well as 6 and 12 months after DBS. The analysis revealed a significant outcome of time on clinical motor tic scores ($F_{1.75,64.92} = 86.68$; $P < .001$; $\pi_p^2 = 0.70$) and phonic tic scores ($F_{1.75,504.69} = 41.41$; $P < .001$; $\pi_p^2 = 0.53$). Mean (SD) motor tic scores improved 38.2% at 6 months of follow-up (from 21.00 [3.72] to 12.97 [5.58]) and 38.5% at 12 months of follow-up (to 12.91 [5.78]). Mean (SD) phonic tic scores improved 44.2% at 6 months of follow-up (from 16.82 [6.56] to 9.38 [6.56]) and 42.7% at 12 months of follow-up (to 9.63 [6.99]). However, YGTSS scores slightly changed between 6 and 12 months: motor tic scores improved 0.5% and phonic tic scores worsened 2.6%; these changes were not statistically significant.

There was a significant interaction of time and target on motor tic scores ($F_{3.51,64.92} = 4.01$; $P < .01$; $\pi_p^2 = 0.18$) and phonic tic scores ($F_{3.50,64.83} = 3.41$; $P = .01$; $\pi_p^2 = 0.16$). The interaction was driven by a greater initial decrease between baseline and 6 months in patients who received the implant in the anterior globus pallidus pars interna (GPi). Mean (SD) motor tic scores among patients who received the implant in the anterior GPi improved 55.8% at 6 months of follow-up (from 22.60 [1.90] to 10.00 [2.51]) at 6 months and 54.9% at 12 months of follow-up (to 10.20 [2.68]), while mean (SD) phonic tic scores improved 46.6% at 6 months of follow-up (from 20.60 [3.11] to 11.00 [3.10]) and 53.4% at 12 months of follow-up (to 9.60 [3.27]) compared with baseline. Mean (SD) motor tic scores among patients who received the implant in the centromedian thalamic region improved 36.6% at 6 months of follow-up (from 20.88 [1.03] to 13.24 [1.36]) and 39.1% at 12 months of follow-up (to 12.71 [1.45]) at 12 months follow-up, while mean (SD) phonic tic scores improved 34.7% at 6 months of follow-up (from 15.41 [1.69] to 10.06 [1.68]) and 38.6% at 12 months of follow-up (to 9.47 [1.77]) compared with baseline. Mean (SD) motor tic scores among patients who received the implant in the posterior GPi improved 26.7% at 6 months of follow-up (from 18.29 [1.03] to 13.41 [1.36]) at 6 months and

Figure. Yale Global Tic Severity Scale (YGTSS) Scores by Time and Brain Target



A, YGTSS motor tic scores at baseline, 6 months, and 1 year. B, YGTSS phonic tic scores at baseline, 6 months, and 1 year. C, Total YGTSS scores at baseline, 6 months, and 1 year. CM indicates centromedian; GPi, globus pallidus internus.

Table 2. YGTSS Preoperative and Postoperative Pooled Scores by Target

Target	YGTSS Score	Baseline		6 mo After Surgery		12 mo After Surgery	
		Patients, No.	Score, Mean (SD)	Patients, No.	Score, Mean (SD)	Patients, No.	Score, Mean (SD)
All	Total	157	75.01 (18.36)	111	44.92 (19.01)[a]	128	41.19 (20.00)[a]
	Motor tic	98	21.00 (3.72)	60	12.97 (5.58)[a]	75	12.91 (5.78)[a]
	Phonic tic	98	16.82 (6.56)	60	9.38 (6.56)[a]	75	9.63 (6.99)[a]
CM thalamic region	Total	51	74.49 (2.28)	51	42.61 (2.71)[a]	51	40.02 (2.70)[a]
	Motor tic	17	20.88 (1.03)	17	13.24 (1.36)[a]	17	12.71 (1.45)[a]
	Phonic tic	17	15.41 (1.69)	17	10.06 (1.68)[a]	17	9.47 (1.77)[a]
Anterior GPi	Total	18	84.33 (11.32)	18	46.50 (15.06)[a]	18	41.78 (15.75)[a]
	Motor tic	5	22.60 (1.90)	5	10.00 (2.51)[a]	5	10.20 (2.68)[a]
	Phonic tic	5	20.60 (3.11)	5	11.00 (3.10)[a]	5	9.60 (3.27)[a]
Posterior GPi	Total	17	63.12 (3.96)	17	50.65 (4.70)[a]	17	45.65 (4.68)[a]
	Motor tic	17	18.29 (1.03)	17	13.41 (1.36)[a]	17	12.47 (1.45)[a]
	Phonic tic	17	11.77 (1.69)	17	9.00 (1.68)	17	7.88 (1.77)[a]
ALIC[b]	Total	3	78.33 (13.58)	3	58.33 (2.89)	4	50.50 (17.99)

Abbreviations: ALIC, anterior limb of internal capsule; CM, centromedian; GPi, globus pallidus internus; YGTSS, Yale Global Tic Severity Scale.

[a] Significant change from baseline at $P < .001$.

[b] The site that targeted ALIC only collected total YGTSS scores, so the motor tic and phonic tic subscale scores are unavailable. ALIC scores were not included in the first rows of data under "All," as they were not included in the analysis owing to small sample size.

31.8% at 12 months of follow-up (to 12.47 [1.45]), while mean (SD) phonic tic scores improved 23.5% at 6 months of follow-up (from 11.77 [1.69] to 9.00 [1.68]) and 33.1% at 12 months of follow-up (to 7.88 [1.77]) compared with baseline. The sample size for the fourth target (ALIC) was too small to draw conclusions (n = 4). The analysis revealed no significant outcome of target on clinical and phonic motor tic scores, suggesting that all 3 major brain targets had a similar overall outcome on the YGTSS motor tic scores ($F_{2,37} = 0.17$; $P = .85$; $\pi_p^2 = 0.01$) and phonic tic scores ($F_{2,37} = 1.23$; $P = .30$; $\pi_p^2 = 0.06$).

YGTSS Total Scores

A significant outcome of time was observed on the YGTSS total score ($F_{1.68,143.01} = 77.92$; $P < .001$; $\pi_p^2 = 0.48$). The mean (SD) YGTSS total score significantly improved 40.1% at 6 months of follow-up (from 75.01 [18.36] to 44.92 [19.01]) at 6 months and 45.1% at 12 months of follow-up (to 41.19 [20.00]) compared with baseline (Table 2). There was a significant interaction between time and target ($F_{5.05,143.01} = 5.64$; $P < .001$; $\pi_p^2 = 0.17$). Mean (SD) total scores among patients who received the implant in the centromedian thalamic region improved 42.8% at 6 months of follow-up (from 74.49 [2.28] to 42.61 [2.71]) and 46.3% at 12 months of follow-up (to 40.02 [2.70]) compared with baseline. Mean (SD) total scores among patients who received the implant in the anterior GPi improved 44.9% at 6 months of follow-up (from 84.33 [11.32] to 46.50 [15.06]) and 50.5% at 12 months of follow-up (to 41.78 [15.75]) compared with baseline. Mean (SD) total scores among patients who received the implant in the posterior GPi improved 19.8% at 6 months of follow-up (from 63.12 [3.96] to 50.65 [4.70]) and 27.7% at 12 months of follow-up (to 45.65 [4.68]) compared with baseline. The score change was driven by the ALIC target group. This group appeared to continue decreasing between month 6 and month 12, whereas the other targets leveled in improvement. This result should be inter-

Table 3. Adverse Events by Target at 1-Year Follow-up

	All Patients (n = 158)		Centromedian Thalamic Region (n = 92)		Anterior GPi (n = 32)		Posterior GPi (n = 34)	
Adverse Event	Events, No.	Cases, No.	Events, No.	Cases, No.	Events, No.	Cases, No.	Events, No.	Cases, No.
Device-related	3	2	3	2	0	0	0	0
Explants	1	1	1	1	NA	NA	NA	NA
Pulse generator removal	2	1	2	1	NA	NA	NA	NA
Surgery-related	7	6	6	5	0	0	1	1
Infections	5	4	5	4	NA	NA	NA	NA
Hemorrhages	2	2	1	1	NA	NA	1	1
Stimulation-related	150	48	70	27	19	7	71	17
Bradykinesia	5	2	NA	NA	NA	NA	5	2
Depression	2	2	2	2	NA	NA	NA	NA
Dysarthria	17	10	6	5	NA	NA	11	5
Dyskinesias	2	2	NA	NA	NA	NA	2	2
Dystonia	4	3	NA	NA	NA	NA	4	3
Exacerbation of tics	3	3	NA	NA	NA	NA	3	3
Gait disorder	2	2	2	2	NA	NA	NA	NA
Lethargy	8	7	3	3	3	3	2	1
Nausea or vertigo	9	9	7	7	2	2	NA	NA
OCD (new or exacerbated)	2	2	NA	NA	NA	NA	2	2
Other	65	30	28	17	3	3	34	10
Paresthesias	15	13	10	8	3	3	2	2
Weight gain (>4.5 kg)	3	3	3	3	NA	NA	NA	NA

Abbreviations: GPi, globus pallidus pars interna; OCD, obsessive-compulsive disorder.

preted with caution, as the sample size for the ALIC group was only 4 participants. The results revealed no significant effect of target ($F_{3,85}$ = 0.67; P = .57; π_p^2 = 0.02). The Figure shows YGTSS scores by target over time.

Adverse Events

Fifty-six of 158 patients (35.4%) reported a total of 160 adverse events during the first year of follow-up (**Table 3**). Most of these adverse events were stimulation related (48 [30.8%]), whereas 6 (3.8%) were surgery related and only 2 (1.3%) were device related. The most frequent adverse events were dysarthria, reported 17 times in 10 of 158 patients (6.3%), and paresthesias, reported 15 times in 13 of 158 patients (8.2%). All of these events were stimulation induced and transitory without major complications, and no deaths were reported. Table 3 shows all reported adverse events per target: dystonia and dyskinesias were more frequently reported in the GPi group, while paresthesias and weight gain were more frequently reported in the thalamic group. One explantation (removal) of the DBS system in the thalamic group was reported owing to infection. The overall infection rate was 2.5% (4 of 158), hemorrhage rate was 1.3% (2 of 158), and total explant rate at 1 year was 0.6% (1 of 158).

Discussion

Outcomes among patients with DBS for Tourette syndrome have been challenging to assess because so few surgical procedures are performed per center per year. The International Deep Brain Stimulation Database and Registry sought to address the paucity of data by using multicountry pooled data. The collective information was designed and shared through a common web portal. The overall goal of combining data was to make it available for long-term process improvement and outcomes. The 1-year data revealed that the population was largely male, with an age range at the time of surgery of 13 to 58 years. Associated comorbidities were commonly reported in our cohort, as expected in patients with Tourette syndrome. Obsessive compulsive-disorder was the most common comorbidity, but depression, anxiety, and attention-deficit/hyperactivity disorder were also common. The proportion of self-injurious behavior was 21.6%, lower than expected for a cohort of patients with severe disease who were selected for surgical intervention.[10] The pooled 1-year outcomes revealed an improvement of 45.1% in the YGTSS total score across all targets used.

Multiple brain targets in this study resulted in similar suppression of tics. This finding was similar to published outcomes of DBS for Parkinson disease where subthalamic nucleus and GPi DBS have both proven to be viable targets for addressing motor dysfunction.[11] When considering each brain target individually, our results reported no significant differences in clinical scores between targets. Although the anterior GPi showed the greatest improvement in the YGTSS total score (50.5%) at 1 year of follow-up, followed by the centromedian thalamic region (46.3%) and the posterior GPi (27.7%), this finding could have been the result of the small sample size of patients who received the implant in the posterior GPi and the degree of baseline impairment across groups, which precludes true head-to-head comparisons. Similar results were observed in a previous systematic review, in which the anterior GPi had the highest mean change (55.3%) on the YGTSS total

score when compared with other targets.[5] Unique to the diagnosis of Tourette syndrome and use of DBS was that the ventral pallidum and the centromedian thalamic region seemed to be the most optimal targets. Both have been regarded as playing important roles in nonmotor basal ganglia circuitry. The similar, but slightly less robust, tic benefit was observed in the pure motor target (dorsal pallidum). The fact that the anterior GPi would have better effects than the posterior GPi is surprising, considering the major differences in nonmotor and motor projections.[12] The benefit from ALIC stimulation was also similar to the other targets. However, the sample size of 5 patients was too small to draw firm conclusions for the ALIC as a target region.

The adverse event profile across targets will be important to understand, particularly for individual patients. A high number of adverse events were reported in the registry, particularly stimulation-induced adverse events, including dysarthria in 6.3% and paresthesias in 8.2% of the cohort, and an overall infection rate of 2.5% and hemorrhagic rate of 1.3%. Our rates at 1 year were low. These rates have been reported to be higher for Tourette syndrome DBS when compared with established rates for DBS and we will need to see if our rates rise over subsequent years of follow-up.[13-15]

Limitations

There are multiple limitations when using a multinational registry and database, which included data from all available patients. The most obvious limitation is that the data come from an observational, descriptive, open-label study with data drawn from multiple sites. Another limitation is the lack of standardized inclusion criteria for inclusion in the registry. We did not consider the potential medication effects on outcomes as these data were not collected. Using data from multiple sites, which may use different surgical techniques or treatment approaches, can also affect results. This limitation could, however, be viewed as an advantage since the total number of cases was high and the experience across groups could be aggregated. However, the number of patients decreased over time, which could render results at 1 year difficult to interpret. Another limitation was that imaging data were not provided to correlate outcomes with DBS targeting; however, the participating centers have future plans to collect imaging data and to examine the active lead location vs outcome. Finally, the numbers for each target were skewed such that there were more centromedian thalamic region and anterior GPi cases. A focus of future data collection will need to be on posterior GPi and ALIC cases so that observations can be expanded, confirmed, or refined.

Conclusions

The first-year results of this multinational electronic collaboration strengthen the notion that DBS could be a potential surgical treatment for select patients with Tourette syndrome. Practitioners should be aware of the high number of stimulation-related adverse events and that these are likely reversible. Larger numbers of patients will need to receive DBS implants across multiple targets and comparison of center-to-center outcomes could help refine the therapy. Publishing multiyear outcomes to a public website (https://tourettedeepbrainstimulationregistry.ese.ufhealth.org/) will improve access to information, improve data sharing, and, we hope, contribute to improvement in outcomes.

ARTICLE INFORMATION

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Correction: This article was corrected on March 12, 2018, to fix an error in the mean (SD) motor tic subscore after 1 year in the Results section of the Abstract, to fix errors in the affiliations of 13 authors, and to add an additional degree for Dr Meng.

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Conflict of Interest Disclosures: Dr Leckman reported serving as an advisor for the European Multicentre Tics in Children Studies (EMTICS) and Tasly Pharmaceuticals LLC; receiving support from the National Institutes of Health (for research projects), the Tourette Association of America, and Grifols LLC; and receiving royalties for books published by John Wiley and Sons, McGraw-Hill, and Oxford University Press. Dr Okun reported serving as a consultant for the National Parkinson Foundation; receiving research grants from the National Institutes of Health, the National Parkinson Foundation, the Michael J. Fox Foundation, the Parkinson Alliance, Smallwood Foundation, the Bachmann-Strauss Foundation, the Tourette Syndrome Association, and the University of Florida Foundation; receiving grants R01 NR014852 and R01NS096008 from the National Institutes of Health for DBS research; receiving royalties for publications with Demos, Manson, Amazon, Smashwords, Books4Patients, and Cambridge (movement disorders books); serving as an associate editor for *New England Journal of Medicine Journal Watch Neurology*; participating in continuing medical education and educational activities on movement disorders (in the last 36 months) sponsored by PeerView, Prime, QuantiaMD, WebMD, Medicus, MedNet, Henry Stewart, and Vanderbilt University; and participating as a site principal investigator and/or coinvestigator for several National Institutes of Health, foundation, and industry-sponsored trials over the years but has not received honoraria. The institution and not Dr Okun received grants from Medtronic, Abbvie, Allergan, and Abbott/St Jude, and Dr Okun has no financial interest in these grants. No other disclosures were reported.

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