Deep brain stimulation of the subthalamic nucleus for advanced Parkinson disease using general anesthesia: long-term results

Clinical article


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Object. The authors analyze long-term outcome in a substantial number of patients who underwent subthalamic nucleus (STN) deep brain stimulation (DBS) surgery under general anesthesia.

Methods. Eighty-two patients underwent bilateral placement of DBS electrodes under general anesthesia for advanced Parkinson disease; the STN was the target in all cases. All patients underwent intraoperative microelectrode recording of the STN. No intraoperative macrostimulation was performed. Unified Parkinson’s Disease Rating Scale (UPDRS) data were recorded in 28 patients. Assessment of outcome was performed using the UPDRS (in 28 cases), the electrophysiological recordings (in all 82 cases), medication reduction (in 78 cases), and complications (in 82 cases).

Results. There was improvement in UPDRS scores across all measures following surgery. The total UPDRS score, off medication, improved from 68.78 (geometrical mean, 95% CI 61.76–76.60) preoperatively to 45.89 (geometrical mean, 95% CI 34.86–60.41) at 1 year postoperatively (p = 0.003, data available in 26 patients). Improvements were obtained in UPDRS Part II (Activities of Daily Living) off medication (p = 0.001) and also UPDRS Part III (Motor Examination) off medication (p < 0.001). Results for the on-medication and on-stimulation states also showed a statistically significant improvement for UPDRS Part III (p = 0.047). Good microelectrode recording of the STN was obtained under general anesthesia; the median first-track length was 4.0 mm, and the median number of tracks passed per patient was 3.0. The median reduction in levodopa medication was 58.1% (interquartile range 42.9%–73.3%). One patient had an intracerebral hemorrhage in the track of 1 electrode but did not require surgical evacuation. One patient had generalized convulsive seizures 24 hours postoperatively and was intubated for seizure control. Unified Parkinson’s Disease Rating Scale scores were obtained in 26 patients at 1 year, 28 patients at 3 years, 17 at 5 years, and 7 at 7 years postoperatively. Up to 7 years postoperatively, there was sustained improvement in the total UPDRS score. The results in these patients showed minimal deterioration in the motor section of the UPDRS over time, up to 7 years following the operation. The authors found no evidence that the UPDRS Part II scores changed significantly over the period of 1–7 years after surgery (p = 0.671, comparison of mean scores at 1 and 7 years using generalized estimating equations).

Conclusions. Long-term outcomes confirm that it is both safe and effective to perform STN DBS under general anesthesia. As part of patient choice, this option should be offered to all DBS candidates with advanced Parkinson disease to enable more of these patients to undergo this beneficial surgery. (DOI: 10.3171/2011.7.JNS11319)

Key Words • subthalamic nucleus deep brain stimulation • Parkinson disease • general anesthesia • long-term outcome • functional neurosurgery

Deep brain stimulation has been shown to be superior to the best medical therapy in improving motor function and quality of life in advanced Parkinson disease.5,11,24,25 The degree of clinical improvement achieved by means of DBS is largely dependent on the accuracy of lead placement.4,15 Smaller studies10,16 involving fewer than 15 patients have demonstrated the feasibility of performing STN DBS surgery under general anesthesia.

This article contains some figures that are displayed in color online but in black and white in the print edition.
We present the long-term outcome in a substantially larger number of patients undergoing STN DBS surgery under general anesthesia.

Methods

Patients

Between October 2002 and October 2009, 82 patients underwent insertion of bilateral STN DBS electrodes under general anesthesia for the treatment of advanced Parkinson disease. The patient group included 62 men (median age at surgery 60.0 years, IQR 54.8–64.0 years) and 20 women (median age at surgery 56.5 years, IQR 53.0–62.3 years).

In every case, 2 consultant neurologists confirmed the clinical diagnosis of Parkinson disease, and all patients fulfilled the United Kingdom Parkinson’s Disease Society Brain Bank criteria (Parts 1 and 2) for the diagnosis of Parkinson disease. All patients were seen in the multidisciplinary movement disorders clinic, which includes a consultant neurosurgeon, a consultant neurologist, and a specialist nurse, prior to surgery. All patients selected for surgery had shown a good response to dopaminergic medication and had developed medically refractory motor fluctuations. Significant cognitive decline was excluded by appropriate psychometric testing prior to surgery, and informed consent was obtained.

Surgical Procedure

The entire surgical procedure was performed under general anesthesia. Induction of anesthesia was performed using boluses of 2 mg/kg body weight propofol and 1 mg/kg remifentanil. A Leksell-G stereotactic frame was applied, and patients were transferred to the MR imaging suite where T1-weighted 3D FSPGR sequences were obtained on a 1.5-T scanner (GE Signa Excite; slab thickness 240 mm, effective thickness 2.4 mm, matrix 320 × 320, TR 14.7, scanning time 7 minutes 30 seconds). To better define the STN, T2-weighted spin echo images were obtained (TR 2200, TE 90, flip angle 90°, slice thickness 2 mm, sequence time 6 minutes 54 seconds).

Images were transferred to the BrainLAB workstation and projected in 3 dimensions (axial, coronal, and sagittal). The anterior commissure and posterior commissure were marked on the FSPGR 3D sequence, and the center of the anterior commissure–posterior commissure line was determined. Using a synthesis of direct visualization of the STN on the T2-weighted images and Benabid’s indirect target 12 mm lateral, 3 mm posterior, and 4 mm inferior to the midpoint of the intercommissural line, the preoperative target was identified, and its coordinates were derived. The ring angle of the stereotactic frame was set at 60° and the arc at 70° or 110° for the right and left sides, respectively. Alterations were made to avoid the lateral ventricles or blood vessels if necessary.

The planned target coordinates were applied to the Leksell frame, and a single semimicroelectrode (FHC Model 22670, typical impedance 0.5–3.0 MΩ) was used to sample neural activity along an initial track targeted at this point. The electrode was advanced 1 mm at a time using a microdrive (FHC microTargeting Drive System), and recordings were made using the Medtronic Leadpoint neural activity monitoring system.

In the first 26 cases, the remainder of the operation was performed using inhalational nitrous oxide and isoflurane. Then there was a general change from inhalational agents to intravenous propofol and remifentanil in our department for all neurosurgical procedures. Thus, in the subsequent 56 cases, intravenous propofol and remifentanil were used for general anesthesia throughout the procedure. Flowtron boots were placed for the duration of the operation, and prophylactic enoxaparin (20–40 mg daily) was administered from 24 hours after surgery until discharge home.

All patients underwent single-track intraoperative MER of the STN (intraoperative microelectrode, Medtronic Ltd.). During this time, there was no change in the depth of anesthesia. Microelectrode recording was started 10 mm above the target and continued until there was no STN pattern, typically up to 5 mm below target. If no STN recording was seen, the electrode was removed and was repositioned 2 mm in the direction of the next best target as judged from MR imaging using a 5-hole array. No intraoperative macrostimulation was performed. The center of MER of the STN determined the final target, and the permanent quadripolar macroelectrode (Medtronic electrode no. 3389) was placed in that location. The electrode was secured by means of the Medtronic Stimloc device. The Leksell frame was then removed.

The patient was then repositioned for tunneling of the wires and insertion of the IPG subcutaneously in the left chest wall—or in the right chest wall for left-handed patients.

Assessment of Outcome

Assessment of outcome was performed using the UPDRS, electrophysiological recordings, change in medication (from preoperative regimen), and complications. Measurement of UPDRS scores is not routine practice at our center. Thus, UPDRS data were obtained in only a subset (28) of our early cohort of patients. Electrophysiological and complications data were available in all patients. Medication data were available in 78 patients due to transfer of care back to their local neurologist.

Statistical Analysis

Paired t-tests were used for paired analysis, where applicable, with the Wilcoxon test used when the assumptions of t-tests were contravened. Generalized estimating equations were used for the analysis of the 7 years of postoperative data. In all analyses, p < 0.05 was considered to represent statistical significance.

Results

The mean patient age at diagnosis of Parkinson disease was 46.8 ± 8.4 years. The patients had Parkinson disease for an average of 10.4 years prior to surgery (geometrical mean, 95% CI 9.4–11.5). Most patients were in the hospital for 4 days (range 3–28 days). The mean duration of the operation was 290 ± 78 minutes.
General anesthesia for STN DBS

Unified Parkinson’s Disease Rating Scale

The UPDRS scores were obtained preoperatively in 28 patients. Postoperative UPDRS data were obtained in 26 patients at the 1-year follow-up appointment, 28 patients at 3 years, 17 patients at 5 years, and 7 patients at 7 years. At the time of data analysis, 7 years had elapsed since surgery in only 10 of the 28 cases in which preoperative UPDRS scores had been obtained. There was improvement in the UPDRS scores across all measures following surgery. Specifically, when comparing scores in the off-medication state, the total UPDRS score improved from 68.78 (geometric mean, 95% CI 61.76–76.60) preoperatively to 45.89 (geometric mean, 95% CI 34.86–60.41) at 1 year postoperatively (p = 0.003; Table 1). Statistically significant improvements were obtained in UPDRS Part II (activities of daily living) off medication (p = 0.001) and also UPDRS Part III (motor examination) off medication (p < 0.001; Table 2).

The UPDRS Part III scores obtained with patients on medication and on stimulation 1 year postoperatively also showed a statistically significant improvement (p = 0.047), although the differences in UPDRS Part II (p = 0.599) and the total UPDRS score (p = 0.228) were not statistically significant.

One year postoperatively, there was also a statistically significant reduction in dyskinesia duration (p < 0.001), disability (p = 0.009), “off” period duration, and unpredictability of “off” period, and sleep was improved (p = 0.020; Table 3).

Over the 7-year period after surgery, there was no significant change in the UPDRS Part II score (p = 0.671, 7 patients). With respect to the UPDRS Part III, there was no significant difference between scores obtained at 1 and 3 years after surgery (p = 0.626). However, comparisons between 1 and 5 years and between 1 and 7 years showed a statistically significant improvement in motor scores (p = 0.002 and p = 0.001, respectively; Table 4).

Electrophysiology

Excellent quality of MER of the STN was obtained under general anesthesia (Fig. 1 upper). The bursting frequency ranged between 25 and 50 Hz, and widening of the background noise baseline was seen. Kinesthetic cells were not sought after.

The mean first-track MER length was 4.0 mm (range 0–9 mm). For the right STN, typically the first operated site, the mean MER length was 4.0 mm (IQR 2–5 mm), and for the left STN it was 4.0 mm (IQR 0.5–5 mm).

The median number of tracks passed per patient was 3. Thus, with most patients, we were able to obtain excellent STN MER on the first track (Fig. 1). With the right STN, the median number of tracks passed was 1, which was the same as for the left STN. Thirty-nine patients—nearly half (47.6%) of the total number of patients—had only 1 track on each side, or 2 microelectrode tracks total.

Medication and Stimulation Parameters

Following STN stimulation, all patients had immediate reduction in their levodopa medication. At the most recent follow-up, 74 patients had a reduction in their levodopa medication (median 58.1%, IQR 42.9–73.3%; Fig. 2). The parameters used were typically 3 V bilaterally, pulse width 60 μsec, rate 130 Hz. Contacts –2 and –6 were the most frequently used; in 80.5% of cases, either of the top 2 electrode contacts were stimulated.

Data regarding antidepressant use were only available in 71 patients. Twenty-one patients were being treated for depression prior to surgery, and 5 of these were able to discontinue their antidepressant medication. However, 13 of the remaining 50 patients (who were not being treated for depression before surgery) required antidepressants following STN DBS (Table 5). This was not statistically significant (p = 0.096).

Complications

One patient had an intracerebral hemorrhage in the track of 1 electrode. This was symptomatic at 48 hours after surgery, but it did not require surgical evacuation. It did lead to a longer inpatient stay than average and rehabilitation for left-sided hemiparesis and double vision, which later resolved. One patient had generalized convulsive seizures 24 hours postoperatively and was intubated for seizure control. Four patients had a postoperative urinary track infection, and 2 patients were discharged home with indwelling catheters due to prostate problems.

Three patients had faulty Kinetra IPGs where bond wires were broken. These patients required subsequent IPG replacement. This problem was recognized by Medtronic; the IPGs had been implanted for 3–6 years.

Following STN stimulation, patients showed a trend toward weight gain. The mean BMI prior to surgery was 25.4 ± 4.6, whereas the mean BMI after surgery was 27.5 ± 5.0.

TABLE 1: Comparison of pre- and postoperative UPDRS total scores on and off medication

<table>
<thead>
<tr>
<th>Variable</th>
<th>Average Preop*</th>
<th>Average 1-Yr Postop*</th>
<th>1-Yr Postop as % of Preop*</th>
<th>p Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>total score—on</td>
<td></td>
<td></td>
<td></td>
<td>0.228</td>
</tr>
<tr>
<td>geometric mean</td>
<td>29.11</td>
<td>24.79</td>
<td>85.14%</td>
<td></td>
</tr>
<tr>
<td>95% CI</td>
<td>22.32–37.97</td>
<td>18.89–32.52</td>
<td>65.10%–111.34%</td>
<td></td>
</tr>
<tr>
<td>total score—off</td>
<td></td>
<td></td>
<td></td>
<td>0.003</td>
</tr>
<tr>
<td>geometric mean</td>
<td>68.78</td>
<td>45.89</td>
<td>66.72%</td>
<td></td>
</tr>
<tr>
<td>95% CI</td>
<td>61.76–76.60</td>
<td>34.86–60.41</td>
<td>51.81%–85.92%</td>
<td></td>
</tr>
</tbody>
</table>

* Values were log-transformed to meet the assumption of normality.
† Paired t-test; comparison of average preoperative and average 1-year postoperative scores.
This increase was statistically significant (p < 0.001, paired t-test).

No patient had a deep venous thrombosis, pulmonary embolism, or pneumonia. One patient attempted suicide after surgery. There was only 1 intensive care unit admission for seizure control, and there were no deaths. No patients had an infection of their implanted DBS system.

**Discussion**

**Patient Benefits of Surgery Under General Anesthesia**

All 82 patients in our study underwent bilateral STN DBS electrode placement under general anesthesia. In our practice, chronic DBS of the STN has been used to treat Parkinson disease since 1999. Our first 20 cases were performed under local anesthesia. Increasing experience with electrophysiological monitoring, to target the STN, gave us the confidence to abandon clinical testing during the procedure. Clinical testing can become unreliable because patients become fatigued. In the absence of intraoperative clinical testing, the administration of general anesthesia to patients with Parkinson disease seemed a compassionate and sensible approach. We already had experience with using general anesthesia for DBS to treat patients with other movement disorders (for example, dystonia).

There are reports of small numbers of patients, describing benefits of surgery under general anesthesia, namely less anxiety, decreased painful dystonia, less back pain, and less anesthetic concerns about respiratory difficulties.10,16 The poor concentration that can affect awake patients’ responses is clearly no longer an issue with general anesthesia. We feel that all patients undergoing the procedure with general anesthesia benefit, as the overall length of the operation is shorter22 (mean 290 minutes), there is more rapid mobilization because the patient is less tired and stressed the day after surgery, and the average length of inpatient stay is only 4 days. As part of the learning curve, our operating time became shorter. Between 2002 and 2004, the average length of an operation was 351 minutes; by 2008–2009, it was 215 minutes.

Zibetti et al.26 found a 4.9% incidence of asymptomatic deep vein thrombosis in patients who underwent surgery with local anesthesia. None of our patients have had their surgery complicated by either a deep venous thrombosis or pulmonary embolism. This may be a result of shorter operating time and more rapid postoperative mobilization.

The shorter operating time also improves patient comfort. Chevrier et al.3 advocate the use of physiotherapy

### Table 2: Comparison of pre- and postoperative UPDRS Parts I, II, and III subscores on and off medication*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Preop</th>
<th>Mean 1-Yr Postop</th>
<th>Mean Difference</th>
<th>p Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>mood</td>
<td>2.73 ± 1.91</td>
<td>3.04 ± 1.80</td>
<td>0.31 ± 1.96</td>
<td>0.430</td>
</tr>
<tr>
<td>ADL—on</td>
<td>10.19 ± 6.00</td>
<td>9.46 ± 5.74</td>
<td>−0.73 ± 6.99</td>
<td>0.599</td>
</tr>
<tr>
<td>ADL—off</td>
<td>21.11 ± 6.66</td>
<td>16.21 ± 6.17</td>
<td>−4.89 ± 5.57</td>
<td>0.001</td>
</tr>
<tr>
<td>motor—on</td>
<td>21.23 ± 11.42</td>
<td>16.77 ± 9.37</td>
<td>−4.46 ± 10.90</td>
<td>0.047</td>
</tr>
<tr>
<td>motor—off</td>
<td>46.11 ± 9.96</td>
<td>31.47 ± 13.37</td>
<td>−14.63 ± 11.41</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

* ADL = activities of daily living.
† Paired t-test.

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### Table 3: Comparison of pre- and postoperative UPDRS Part IV subscores*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Change From Preop to 1-Yr Postop</th>
<th>Total</th>
<th>p Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reduction</td>
<td>Increase</td>
<td>No Change</td>
</tr>
<tr>
<td>dyskinesia duration</td>
<td>21</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>dyskinesia disability</td>
<td>14</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>dyskinesia pain</td>
<td>8</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>early morning dystonia</td>
<td>8</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>offs predictable</td>
<td>8</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>offs unpredictable</td>
<td>9</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>offs sudden</td>
<td>11</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>offs duration</td>
<td>14</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>anorexia, nausea, vomiting</td>
<td>3</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>sleep disturbances</td>
<td>8</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>symptomatic orthostasis</td>
<td>1</td>
<td>0</td>
<td>13</td>
</tr>
</tbody>
</table>

* Values represent numbers of patients unless otherwise indicated.
† Wilcoxon rank-sum test.
General anesthesia for STN DBS during DBS surgery for Parkinson disease. However, they noted that, in their center, the average duration of surgery was 12 hours. Our quicker procedure obviates the need for intra-procedural physiotherapy and extra personnel within the operating room, which may help to reduce the infection risk. Other studies have confirmed that more rapid lead placement improves patient comfort.21

To improve patient comfort, we also routinely operate without shaving the patient’s hair. We have had no cases of infection in our patients undergoing STN DBS. Plaha et al.19 also reported an incidence of 0% infection in a series of cases in which DBS electrodes were implanted without hair shaving.

Intraoperative MER Under General Anesthesia

All of our patients had intraoperative MER of the STN. Intraoperative MER has been shown to be effective in determining the boundaries and size of the STN.13 During the time of MER, there was no change in the depth of anesthesia. Patients continued to receive either inhaled nitrous oxide and isoflurane or the combination of propofol and remifentanil. We were able to obtain excellent MER of the STN and there was no difference in the quality of MER in the 2 types of anesthesia.22 This is in contrast to other series in which the level of anesthesia was reduced to obtain MER.10 Microelectrode recording was obtained on average across 4 mm. Better recording was seen on the first operated site, and less MER tracks were made on this side. We alter the final target in most cases based on MER, but most of our alterations are in depth rather than involving second tracks.1 This is in keeping with our earlier reported series demonstrating that CSF leakage occurring during the time interval to operating on the second side may be responsible for brain shifts and that electrophysiology probably provides an objective measure of these errors in real time.9 Postoperative imaging is not routinely performed to verify final electrode positioning. Initially, we performed postoperative MR imaging in all our patients to prove accuracy.9 Accuracy was proven in the first 35 patients, and now we only perform postoperative MR imaging if there is clinical concern.

The increased risk of hemorrhage with MER is well documented, with a higher risk in hypertensive patients and those in whom multiple passes are performed.7 To minimize the risk of hemorrhage, we do not perform macroelectrode stimulation, and only a single MER track is placed initially. A second track is placed only if there is no or only poor STN recording. Of 235 tracks placed in this study population, only 1 was associated with hemorrhage—a figure that compares favorably with studies in which MER is avoided.6 The lack of feedback from limb

![Fig. 1. Upper: Microelectrode recording of the STN. The characteristic spikes of firing from the STN are seen from 3 mm above to 1 mm below the target proposed on the basis of MR imaging. Lower: Total number of tracks passed per patient.]

![Fig. 2. Change in levodopa medication as of the most recent follow-up examination.]

### Table 5: Antidepressant use before and after surgery

<table>
<thead>
<tr>
<th>Preop Depression</th>
<th>Postop Depression (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
</tr>
<tr>
<td>no</td>
<td>37</td>
</tr>
<tr>
<td>yes</td>
<td>5</td>
</tr>
<tr>
<td>total</td>
<td>42</td>
</tr>
</tbody>
</table>

* In the 71 patients for whom complete data regarding antidepressant use were available in the case notes.
movements during macrostimulation did not appear to affect our results. Placement of any electrode in the STN causes a "placement effect." It becomes difficult, if not impossible, to tell whether a clinical improvement has been caused by the currently placed electrode or a previously placed one. 8

In the majority of our patients, effective stimulation was achieved on contacts -2 and -6 of the quadripolar electrode, which is consistent with other studies. These have shown that the effective area of stimulation is in the upper part of the STN recording area. 13 The stimulation parameters of 3 V, pulse width 60 μsec, rate of 130 Hz is comparable to those published in current literature. 12,20 This was achieved by increasing the voltage by 0.1 V weekly with concurrent medication reduction until a voltage of 3 V was achieved. Stimulation-related side effects were generally not seen except when the voltage was turned up high (for example, to 4.5 V) during assessment of all electrodes to determine the best for long-term stimulation.

Long-Term Patient Outcome and General Anesthesia

At 1 year after surgery, there was improvement in the total UPDRS score from 68.78 to 45.89 off medication (p = 0.003). Up to 7 years postoperatively, there was sustained improvement in the total UPDRS. Our results in this series of patients show minimal deterioration in the motor section of the UPDRS with time, up to 7 years following the operation. We found no evidence that the UPDRS Part II activities of daily living of patients changed significantly over the period of 1–7 years after DBS surgery (p = 0.671, comparison of mean scores at 1 year [26 patients] and 7 years [7 patients] using generalized estimating equations). The apparent improvement in these UPDRS motor scores at 7 years postoperatively may well be skewed by the fittest patients returning for follow-up; some patients may have dropped out due to death in the aging patient population. Van Blercom et al. 23 have reported long-term improvement in Parkinson disease symptoms for up to 3 years; Krack et al. 11 with follow-up of 5 years. Thus, our study has one of the longest long-term results. Parkinson disease is a degenerative condition in which mobility deteriorates over time. 17 It is remarkable how this group of patients has maintained their mobility over time, years after DBS surgery. This may help us to understand how DBS works and offer further insights into the disease process and future treatments.

The median reduction in levodopa was 58.1% at last follow-up, with improved mobility compared with the pre-operative state, which indicates that the DBS is having the desired effect in our patients. Limousin et al. 19 (reporting on patients undergoing surgery under local anesthesia) also showed that levodopa doses decreased by an average of 60%. Thus, performing the operation under general anesthesia has the same efficacy as performing the operation under local anesthesia.

One patient attempted suicide 4 months after surgery. This patient had a history of depression that was not known to us at the time of surgery. There was also an increased use of antidepressants in the years after surgery in our group of patients, although this was found to be statistically nonsignificant. This finding is in keeping with those of other studies. Permanent apathy was seen in 10.2% of patients after their third postoperative year in the series by Krack et al., 11 although apathy was not apparent in our series. The literature reports a suicide rate of 0.16%–0.32%, with an average time to suicide of 2.4 years. 2 However, in the PD SURG trial that enrolled 366 patients, none committed suicide. 25 In a group of Parkinson disease patients not undergoing surgical intervention, 4.3% reported having attempted suicide; 16 thus, suicide and suicide attempts may not be related to surgery but to the underlying disease.

Our patients had a mean BMI increase of 2.1 kg/m 2 following surgery. This increase is in keeping with the results of other studies 2 and may be due to a reduction in dyskinesia, the increased independence of the patient to obtain food, or a possible direct drive to eat. Increased BMI could cause further problems with mobility, however, and in the current climate of rising obesity, all patients should be counseled with regard to this side effect of STN DBS.

Conclusions

Long-term outcomes confirm that it is both safe and effective to perform STN DBS surgery under general anesthesia. As part of patient choice, it should be offered to all patients with Parkinson disease who are candidates for DBS to enable more patients with advanced disease to undergo this beneficial surgery.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Harries, Mitchell. Acquisition of data: Harries, Kausar, Roberts, Mocroft, Pall, Mitchell. Analysis and interpretation of data: Harries. Drafting the article: Harries. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Harries. Statistical analysis: Hodson. Study supervision: Mitchell.

References

General anesthesia for STN DBS


