Objective: To evaluate the effects of ventroposterior pallidotomy on motor disability and on behavior and cognition in patients with medically intractable idiopathic Parkinson disease.

Design: Detailed motor testing both while receiving and discontinuing levodopa medication, posturography, and neurocognitive and behavioral assessments were performed before and 3 to 6 months after unilateral ventroposterior pallidotomy.

Setting: University-based movement disorder program.

Patients: Thirty-two patients without dementia with medically refractory idiopathic Parkinson disease were studied.

Main Outcome Measures: Motor function and disability were measured using the Unified Parkinson’s Disease Rating Scale, Hoehn and Yahr stage, and the Schwab and England Activities of Daily Living Scale. Dynamic balance was measured by sway (amplitude and velocity) using the Chattecx Balance System. Detailed cognitive and behavioral assessments were also performed both before and after surgery.

Results: Eighty-three percent of patients experienced improvement of their total Unified Parkinson’s Disease Rating Scale score at 3 to 6 months after surgery. Significant improvements were also seen in the contralateral Unified Parkinson’s Disease Rating Scale motor subscore (78%) as well as in the contralateral Unified Parkinson’s Disease Rating Scale total score both during the on and off period (78% and 79%, respectively). The Hoehn and Yahr stage, Schwab and England Activities of Daily Living Scale score, and dynamic balance when standing on foam also improved following unilateral pallidotomy in many patients. Cognitive performance remained relatively unchanged following surgery with the exception of category fluency, which exhibited a modest decline ($P < .04$). A significant improvement in depression was found on the Beck Depression Inventory.

Conclusions: Ventroposterior pallidotomy significantly improves motor performance and daily level of function in Parkinson disease. Cognition and behavior are not adversely affected in patients without dementia, and a cognitive screening battery is proposed.

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In recent years, the use of radiofrequency ventroposterior pallidotomy (VPP) as a symptomatic treatment for the medically refractory motor symptoms of Parkinson disease (PD) has been gaining widespread acceptance. A number of centers have reported significant improvements in controlling disabling dyskinesias, on/off fluctuations, and other motor symptoms in patients with idiopathic PD. Although gait and balance are often but not uniformly improved with VPP, a detailed analysis of the impact of this procedure on balance has not been undertaken. In addition, as our understanding of basal ganglia circuitry increases, the relationship between frontal cortex and the basal ganglia and its role in cognition and behavior are becoming more fully appreciated.

Work by Alexander and coworkers’ revealed a series of 5 distinct, parallel, frontal-subcortical circuits that link specific areas of the frontal lobe to specific areas within the striatum, globus pallidus/substantia nigra, and thalamus. Three of the 5 have direct cognitive and behavioral relevance and originate in the dorsolateral prefrontal cortex, the lateral orbital frontal region, and the anterior cingulate cortex, respectively. Disruption at any level within these discrete frontal-striatal-thalamocortical pathways can produce characteristic neurobehavioral and neuropsychiatric syndromes and may underlie the cognitive and behavioral changes that are frequently seen in individuals with PD. Earlier pallidotomy procedures re-
PATIENTS AND METHODS

PATIENT SELECTION

Patients were screened for possible pallidotomy by both a neurosurgeon (A.D.) and a neurologist (D.M. or J.M.B.) in the Movement Disorders Clinic at the University of California, Los Angeles. Selection was based on the following criteria: (1) a history consistent with a diagnosis of idiopathic PD including 2 of the 4 cardinal features: tremor, bradykinesia, rigidity, and/or gait disturbance/postural instability; (2) a history of symptoms responsive to the use of levodopa; (3) medically refractory parkinsonian symptoms, particularly marked on/off fluctuations and/or dose-limiting or disabling dyskinesias; (4) no serious, active medical illnesses; and (5) an absence of overt dementia according to criteria of the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition.10 Patients with secondary parkinsonism, multiple system atrophy, or other degenerative or structural brain diseases were excluded. Additionally, only patients whose primary language was English were included for detailed cognitive and behavioral testing. Thirty-six patients, with a mean ± SD age of 65 ± 9 years (range, 34-82 years), met entry criteria for the study and were enrolled from March 1995 through October 1996. The average ± SD duration of symptoms in this patient group was 13.5 ± 6.4 years (range, 6-30 years) with an average age of onset of 51.5 ± 10 years (range, 27-66 years). The average preoperative daily levodopa equivalent dosage was 885.8 mg (100 mg of regular levodopa = 130 mg of controlled-release levodopa = 10 mg of bromocriptine = 1 mg of pergolide mesylate).11

CLINICAL EVALUATIONS

Motor and Functional Assessment of PD

Patients were evaluated preoperatively and at 3 to 6 months after surgery. Medications were optimized before surgery and patients maintained a stable medication regimen for at least 1 month before surgery. Patients were evaluated while receiving and while discontinuing medications during their on or off period. Patients arrived at the clinic having discontinued antiparkinsonian medications since the previous night (approximately 12 hours) and were instructed to take their usual morning dose of antiparkinsonian medications after the initial videotape and motor evaluation. The “on” examination was performed at variable intervals after medication administration depending on the patient’s clinical response. The patient’s best on state was determined subjectively by patient report. The Unified Parkinson’s Disease Rating Scale12 (UPDRS) and Hoehn and Yahr staging13 (H&Y) were determined for both the on and off conditions. The Schwab and England Activities of Daily Living Scale14 score was also determined for patient’s best on state and typical off state. In addition to the total UPDRS score, off subscores of the UPDRS were also analyzed and included the motor subscore (UPDRS part 3, questions 18-31), the activities of daily living score (UPDRS part 2), a bradykinesia score (UPDRS questions 23-26 and 31), tremor score (UPDRS questions 16, 20, and 21), rigidity score (question 22), gait/balance score (UPDRS questions 13, 14, 15, 29, and 30) and treatment fluctuations (UPDRS questions 37-39), and treatment complication scores (UPDRS part 4).

Posturography

Posturography was performed in patients while receiving medication. The Chattecx Balance System (Model No. 5017, Chattecx Corporation, Hixon, Tenn) was used to determine static and dynamic sway. This system uses vertical force transducers to determine instantaneous fluctuations in the center of pressure.15 Velocity of sway in the medial-lateral and anterior-posterior direction on static (with and without foam) and dynamic posturography was measured in 18 patients before surgery and was repeated again at 3 to 6 months after surgery. Ten age-matched control subjects were also included in the analysis. The standard test battery included measurements of sway for 10 seconds with eyes open and closed under each of 4 conditions: (1) platform still (static), (2) foam rubber (thickness, 7.5 cm; density, 2.5 kg/m3; Specialty Composites Corporation, Indianapolis, Ind) on a still platform, (3) platform dynamically tilting in the anterior-posterior direction (0.01 Hz, 4° peak amplitude), and (4) platform dynamically tilting in the medial-lateral direction (0.01 Hz, 4° peak amplitude). Details of the analysis have been previously described.15 The best of 3 trials was used for analysis and patients were excluded if they fell over on all 3 trials. For statistical analysis, we used a multivariate approach to repeated measures analysis of variance.

Neuropsychological and Neuropsychiatric Test Battery

A selective cognitive test battery that took approximately 1 hour was administered to 32 patients before surgery and again at 3 to 6 months after surgery. All patients were tested in the on condition as determined by patient report and observations made by the examining neurologist (D.M.). This focused test battery consisted of the Mini-Mental State Examination (MMSE),16 forward digit span, 15-item subset of the Boston Naming Test, 10-word shopping list,17 Trail-Making parts A and B, verbal category fluency, Ruff Figural Fluency,18 every other item from the first 20 of the Visual-Verbal test,19 and Stroop color-word test.20 The neuropsychiatric assessments included the Neuropsychiatric Inventory,21 a validated, caregiver-based, behavioral assessment tool that addresses changes in both the frequency and severity of the 10 following discrete behaviors: delusions, hallucinations, agitation, depression/
dysphoria, anxiety, euphoria/elation, apathy/indifference, disinhibition, irritability/ability, and aberrant motor behavior. In addition, the Beck Depression Inventory, a self-rated depression instrument, was also used and selected specifically because it places less emphasis on the somatic symptoms associated with depression that may present an important confounding variable in this patient population. Additionally, this instrument has been used widely in patients with PD. Moreover, an apathy scale developed for use in patients with PD was also administered.

SURGICAL AND LOCALIZATION TECHNIQUES

Targeting

Preliminary lesion targets were calculated from magnetic resonance imaging scans taken immediately before surgery with the headframe in place (Leksell Model G, Elekta Instrument, Atlanta, Ga.). Fiducial marker plates attached to the frame provided a means of relating the magnetic resonance imaging-based measurements to the Leksell stereotactic space. Targets were initially chosen based on the schema proposed by Laitinen et al. The coordinates were then modified based on visual assessment of the basal ganglia anatomy with respect to the posterior aspect of the mamillary bodies, internal capsule, and optic tract on coronal sections taken orthogonal to the anterior commissure/posterior commissure line. An electrode track was chosen that provided an angle of approximately 30° anteriorly and 10° laterally, with the burr hole placed approximately 4 cm lateral to the midline and at the level of the coronal sulature. This track helped minimize risk to the optic tract. Immediately following the operation, the patient was rescanned with the fiducial marker plates in place so that the actual lesion site could be compared with the preoperative and actual target coordinates.

Stimulation/Recording

Intraoperative electrical stimulation was provided by a stimulation lesion generator (Model RFG-3C, Radionics Inc, Burlington, Mass). The stimulation consisted of trains of constant voltage monopolar, biphasic 1-millisecond pulses at 2 Hz and 30 Hz, using a patch electrode placed over the contralateral scapula as a reference. The electrode dimensions were 1.25 mm in diameter with a 2-mm exposed tip (Radionics Inc.). Stimulus voltage was increased at each frequency from 0 V to a limit of 4 V or to a perceptible motor response. Because the internal capsule consists of final common path motor fibers, a single stimulation pulse can produce a motor response. Phasic motor activation with 2-Hz stimulation was therefore assumed to be mediated through the internal capsule, with the voltage threshold roughly proportional to the proximity of the electrode to the internal capsule. Temporal summation of postsynaptic effects of stimulation at 50 Hz can produce effects across relatively diffuse polysynaptic neural systems, and we found that 50-Hz stimulation of the VPP lesion will typically produce an exacerbation of parkinsonian motor symptoms such as tremor or dystonic posturing. We took such a response as an indication that the electrode was within the VPP area. Motor responses were observed by a neurologist (J.M.B.), and the stimulation threshold was defined as the amplitude that produced an observable behavioral response. At a given electrode position, we first obtained the threshold by increasing amplitudes from 0 V to a desired threshold of 2 Hz or to a maximum of 4 V. We then obtained the threshold for exacerbation of parkinsonism with stimulation of 50 Hz. Microelectrode recording was obtained with a bipolar microelectrode (Radionics 5ME-E [Radionics Inc], tip impedance, 100 kΩ at 1 kHz) advanced through one tract only from 4 mm above the selected target until 1 mm beyond. This allowed confirmation of cellular hyperactivity at the VPP target, as well as confirmation that the lesion would be placed at least 1 mm above the optic tract lying caudal to the VPP.

Lesioning Technique

Three lesions were made for 60 seconds at 75°C to 80°C at 2-mm increments. All patients were examined during the procedure by the neurologist (J.M.B.) while the temperature at the electrode was held at 50°C. This measure gave a glimpse of possible undue effects that could happen when the final lesion of 75°C to 80°C was placed. Electromyographic electrodes were also used to determine threshold voltages and resting motor activity. Electromyographic reading was recorded from: (1) the face at the anterior margin of the contralateral masseter muscle, thereby including muscles of mastication as well as facial expression; (2) across the flexor and extensor compartments of the contralateral forearm, thereby including some muscles of the elbow as well as both flexors and extensors of the fingers; and (3) across the contralateral thigh.

STATISTICAL ANALYSIS

The total UPDRS score was derived from the summation of the mentation, behavior, and mood score (maximum, 16), the activities of daily living score (maximum, 52), the motor examination both ipsilateral and contralateral (maximum, 108), and the complications of therapy score (maximum, 23). Contralateral UPDRS scores both while receiving and not receiving medications were determined as above with the exception of using only contralateral motor scores.

The Wilcoxon sign rank test for matched pairs was used to assess motor scores before and after surgery. A multivariate analysis of variance approach to repeated measures was used in posturography comparisons in all test conditions. Pairwise t tests were used to compare psychometric and behavioral data before and after surgery.
verse dorsomedially, anteriorly, and laterally to the glo-
bus pallidus. We therefore hypothesized that no ad-
verse cognitive or behavioral sequelae would result from
such a lesion, and that VPP can improve initiation and
cognitive flexibility.

RESULTS

Thirty-six patients met entry criteria for the study and
were enrolled from March 1995 through October 1996.
Of these 36 patients, 32 (24 men and 8 women) with a
mean ± SD age of 65.3 ± 9.3 years (age range, 34-82 years)
completed both preoperative and 3 to 6 months postop-
erative testing. Four patients did not return for follow-up examination. All 4 patients were from out of
state and a telephone follow-up was conducted for
them. One patient could not afford to fly back from
Hawaii, but was doing well with reported improvement
in his parkinsonian symptoms, 2 patients experienced
no clinical benefit from the surgery but had no adverse
consequences and did not wish to fly back for a
follow-up examination, and 1 patient reported improve-
ment in his parkinsonian symptoms, but his wife had
become seriously ill and they could not return for a
follow-up visit.

MOTOR SCORES

Eighty-three percent of patients experienced improve-
ment on the total UPDRS score at 3 to 6 months after
surgery. Significant improvements were seen in the mo-
tor subscore (78%) as well as in the contralateral total
UPDRS scores both on and off (78% and 83% of pa-
tients, respectively). The magnitude of improvement was
23% (Figure 1 and Table 1). Hoehn and Yahr stage
improved in the on condition in 55% of patients and in
41% in the off condition.

Two patients were a H&Y stage I in the on condi-
tion and both improved to stage 0 following surgery. While
in general, patients with a H&Y stage I would not be con-
sidered for surgical inervention, both patients had been
mildly affected with unilateral tremor predominant symp-
toms and dose-limiting dyskinesias, and although their
symptoms were responsive to the use of levodopa, they
were unable to tolerate any advances in the medication.
We were reluctant to perform the operation since the
symptoms seemed mild, but to the patient they were dis-

Table 1. Pallidotomy Clinical Dataa

<table>
<thead>
<tr>
<th>Category</th>
<th>No. of Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent of Improvement</td>
<td></td>
</tr>
<tr>
<td>Improved</td>
<td>No.</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------</td>
</tr>
<tr>
<td>Total UPDRS (off)</td>
<td>20/24</td>
</tr>
<tr>
<td>Contralateral UPDRS (on)</td>
<td>21/27</td>
</tr>
<tr>
<td>Contralateral UPDRS (off)</td>
<td>19/24</td>
</tr>
<tr>
<td>Motor score (off)</td>
<td>25/32</td>
</tr>
<tr>
<td>Tremor</td>
<td>18/24</td>
</tr>
<tr>
<td>Rigidity</td>
<td>12/24</td>
</tr>
<tr>
<td>Gait</td>
<td>19/24</td>
</tr>
<tr>
<td>Bradykinesia</td>
<td>17/24</td>
</tr>
<tr>
<td>Freezing</td>
<td>16/31</td>
</tr>
<tr>
<td>H&amp;Y (on)</td>
<td>17/31</td>
</tr>
<tr>
<td>H&amp;Y (off)</td>
<td>13/32</td>
</tr>
<tr>
<td>S&amp;E (on)</td>
<td>20/31</td>
</tr>
<tr>
<td>S&amp;E (off)</td>
<td>18/23</td>
</tr>
<tr>
<td>ADL subscore</td>
<td>20/29</td>
</tr>
<tr>
<td>Complication</td>
<td>28/32</td>
</tr>
<tr>
<td>Mean off time</td>
<td>16/32</td>
</tr>
<tr>
<td>Dyskinesias, %</td>
<td>21/32</td>
</tr>
<tr>
<td>On/off fluctuations</td>
<td>25/32</td>
</tr>
</tbody>
</table>

a UPDRS indicates Unified Parkinson’s Disease Rating Scale; on, patients are receiving medication and are in their best motor state; off, medication has worn off; H&Y, Hoehn and Yahr stage; S&E, Schwab and England Activities of Daily Living Scale; and ADL, activities of daily living.
†Wilcoxon matched pairs signed rank test.
abling and a major source of distress. Following surgery in both cases, the outcome was extremely beneficial and both of these patients have remained well for more than 1 year. Twenty-eight patients were H&Y stage III or IV (off) before surgery and of these, 12 improved, 15 had no change in H&Y stage, and 1 worsened.

The Schwab and England Activities of Daily Living Scale scores also improved in 65% of patients both in the on and off state or condition. Analysis of the motor subscores from the UPDRS demonstrated significant improvement in all parkinsonian motor symptoms (Figure 2).

The magnitude of improvement ranged from 19% to 61% with the greatest improvement being found in treatment complications. Twenty-eight (88%) of 32 patients experienced benefit in this study, particularly with regard to reduction or resolution of dyskinesias (Table 1).

Medications as measured in levodopa equivalents remained unchanged in 44% of patients. Nineteen percent of patients required a decreased levodopa dosage by 5% to 25%, another 16% by 26% to 50%, and 6% by 51% to 75%. Fewer patients required an increase in levodopa dosage: 9% increased by 5% to 25% and 6% increased by 26% to 50%.

Complications from unilateral pallidotomy were rare. Transient contralateral facial weakness lasting less than 24 hours occurred in 1 patient. Transient postoperative confusion lasting less than 48 hours was seen in 4 patients. Two of these patients had a borderline cognitive performance before surgery and subsequently went on to show clear evidence of persistent cognitive and behavioral deterioration at 3 months after surgery and beyond despite good lesion placement (Figure 3).

**POSTUROGRAPHY**

Sway velocity was significantly increased (P<.01) in patients (before surgery) compared with controls for both medial-lateral and anterior-posterior directions for all test conditions (static, foam, and tilting) (Figure 4). Although there was a trend toward less sway on all postoperative tests compared with preoperative tests, the difference was significant (P<.05) for the foam test condition only (Figure 4).
The motor symptoms of PD are significantly improved and good functional outcomes are experienced following unilateral VPP in the vast majority of patients. These results are in keeping with findings from other centers. As in other studies, the most responsive symptoms to VPP were medication-induced dyskinesias, tremor, rigidity, and freezing. Unlike some previous studies, we observed significant improvement in both the on and off condition. Much of the improvement while receiving medications may be accountable for reduction in dyskinesias. Not only were the motor scores improved but patients also experienced good functional benefit following VPP, which is reflected in the improvement in the Schwab and England Activities of Daily Living Scale scores. It must be emphasized, however, that this was not a double-blind study and a potential for placebo response cannot be fully omitted. Nonetheless, benefit was experienced by the vast majority of patients at all levels of severity and benefit has been maintained for most patients who have been evaluated at 1- and 2-year follow-up (complete long-term follow-up data are still pending, however).

To evaluate balance, we measured sway using the Chattecx Balance System. Disturbance in balance is a common clinical problem for patients with PD and contributes to falls, injury, and significant morbidity. Objective measures of balance in patients with PD using posturography has yielded variable findings, but in general patients with PD show spontaneous body sway in excess of that in normal elderly individuals presented in some studies and no difference in others and perform best in the on condition. In this series of 18 patients, we found that patients with PD (H&Y stages I-IV) exhibited significant difference in body sway before surgery compared with normal age-matched controls. Unilateral VPP surgery resulted in improvement in sway velocity when standing on foam and there was a trend toward decreased sway on a stable and moving platform 3 to 6 months after surgery. Since patients were tested in the on state, improvements in sway may be secondary to the decrease in dyskinesias. To our knowledge, this is the first report in the literature of improved balance as measured by posturography following unilateral pallidotomy for idiopathic PD.

Mild cognitive deficits occur commonly in patients with PD, affecting up to 40% without overt dementia. The most prominent abnormalities occur in higher executive skills that include abilities such as switching and maintaining set (cognitive flexibility), abstract reasoning, planning, and initiation. In addition, patients with PD also frequently have difficulty with visuospatial skills and memory retrieval. Commonly used screening instruments for dementia do not routinely assess frontal systems tasks and thus our study undertook to use a directed cognitive assessment battery that focused on frontal function in addition to assessing other cognitive domains. The MMSE, a commonly used mental status screening tool, has been used primarily to detect cortical dementias such as Alzheimer disease and is fairly insensitive to cognitive changes seen with subcortical de-

### Table 2. Neuropsychological Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Mean ± SE Before Surgery</th>
<th>Mean ± SE After Surgery</th>
<th>Change</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMSE</td>
<td>28 ± 0.3</td>
<td>28 ± 0.5</td>
<td>-0.4</td>
<td>.30</td>
</tr>
<tr>
<td>15-BNT</td>
<td>14 ± 0.3</td>
<td>14 ± 0.2</td>
<td>0.2</td>
<td>.50</td>
</tr>
<tr>
<td>Delayed Recall</td>
<td>6 ± 0.4</td>
<td>6 ± 0.5</td>
<td>0.3</td>
<td>.50</td>
</tr>
<tr>
<td>Recognition</td>
<td>9 ± 0.2</td>
<td>9 ± 0.3</td>
<td>-0.4</td>
<td>.60</td>
</tr>
<tr>
<td>Verbal Fluency</td>
<td>11 ± 1.1</td>
<td>11 ± 1.0</td>
<td>-2.0</td>
<td>.04</td>
</tr>
<tr>
<td>Visual-Verbal</td>
<td>17 ± 0.5</td>
<td>16 ± 0.8</td>
<td>-0.9</td>
<td>.10</td>
</tr>
<tr>
<td>Stroop A</td>
<td>120 ± 1.9</td>
<td>118 ± 2.5</td>
<td>-1.3</td>
<td>.80</td>
</tr>
<tr>
<td>Stroop B</td>
<td>77 ± 1.9</td>
<td>78 ± 1.8</td>
<td>1.0</td>
<td>.50</td>
</tr>
<tr>
<td>Stroop C</td>
<td>44 ± 2.0</td>
<td>46 ± 2.8</td>
<td>-0.9</td>
<td>.40</td>
</tr>
<tr>
<td>Trail-Making part A</td>
<td>52 ± 5.9</td>
<td>63 ± 15.0</td>
<td>13.0</td>
<td>.30</td>
</tr>
<tr>
<td>Trail-Making part B</td>
<td>228 ± 26.8</td>
<td>219 ± 30.3</td>
<td>-0.5</td>
<td>.80</td>
</tr>
<tr>
<td>Design Fluency</td>
<td>61 ± 4.5</td>
<td>61 ± 6.9</td>
<td>-0.1</td>
<td>.90</td>
</tr>
</tbody>
</table>

* MMSE indicates Mini-Mental State Examination; BNT, Boston Naming Test.
† Verbal fluency showed a statistically significant decline (P < .04).

### NEUROPSYCHOLOGICAL TEST RESULTS

Thirty patients completed the selective cognitive and behavioral test battery. One patient was excluded from analysis for the neuropsychological data because he was blind secondary to a remote history of retinal artery occlusion in one eye and macular degeneration in the other and could not complete many of the tests. Another patient was excluded on the basis of incomplete data related to scheduling conflicts.

Cognitive performance remained relatively unchanged following surgery with the exception of category fluency, which exhibited a modest, but statistically significant decline (P < .04) (Table 2). Two patients with a borderline cognitive performance before surgery showed clear evidence of persistent cognitive and behavioral deterioration at 3 months after surgery and beyond. The MMSE score was insensitive at detecting mild dementia. Both patients who experienced a significant postoperative cognitive decline had MMSE scores within the age-matched normal range. No single frontal test predicted a poor cognitive outcome, but falling 2 SDs below the mean on at least 3 of the 5 frontal tests administered was found in the 2 patients who exhibited postoperative cognitive decline. These 2 patients were further characterized by a poor performance on delayed free recall on the shopping list test. Neuropsychological test results for dominant and nondominant hemisphere lesions in only the right-handed patients did not result in any statistically significant differences for any of the parameters tested.

### RESULTS OF NEUROPSYCHIATRIC ASSESSMENT

A significant decline in Beck Depression Inventory score (P < .02) was observed. This was not explained by any additional treatment with antidepressant medications. Neither the total Neuropsychiatric Inventory score nor any of the subscores of the 10 discrete behaviors changed significantly after surgery. Similarly, the apathy scale also was without significant change following VPP.
mentias. All patients in this series had MMSE scores within the age- and education-matched normal range. In our study, 60% of patients exhibited a performance of 1 SD below the age-matched mean in at least 1 of the frontal tasks. In general, however, poor preoperative performance on frontal tasks alone did not predict cognitive deterioration after surgery. Poor delayed recall on a superspan memory test identified the 2 patients with exhibited poor cognitive outcomes. One patient had an amnestic pattern of memory loss more consistent with Alzheimer disease. He progressed further after surgery and developed a moderately severe dementia most consistent with concomitant Alzheimer disease and with PD. By using a cutoff score of 5/10 on delayed free recall to identify those with some memory difficulty (n = 12), the 2 patients who had poor cognitive outcomes were clearly identified. The continuing cognitive decline seen in these 2 patients occurred despite having well-placed surgical lesions without intracranial complications.

Longer-term follow-up is required for patients following VPP not only with regard to length of improvement of the motor symptoms but also with regard to any change in the subsequent rate of development of dementia or mood changes. In a small series motor improvements have been demonstrated to last at least 4 years. From the findings in this study and reports from other centers, excluding patients with even mild dementia is imperative and we propose that these patients can be identified with appropriate screening.

Mood changes and behavioral symptoms, particularly depression, anxiety, and apathy, also coexist in high frequency with PD and may involve the orbitofrontal and cingulate prefrontal circuits. We set out to examine both the severity and frequency of these behaviors in patients following surgery. No patient met Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition criteria for major depression and mild depressive symptoms significantly improved at 3 months following surgery without the further addition of antidepressant medication. Furthermore, no serious problem behaviors developed in any of the patients without dementia as a result of surgery. (In a recent article, Soukop et al found no significant change in cognitive functioning following unilateral VPP in 14 patients, which further supports the findings presented herein.)

We submit that not all patients require complete neuropsychological testing prior to undergoing unilateral pallidotomy surgery, but that adequate screening for dementia is imperative. The MMSE alone lacks enough detail to uncover minor cognitive difficulties; nonetheless, it serves as a useful screening tool to detect obvious cognitive difficulties and can be a helpful adjunct in patient selection. In addition, more extensive assessment of memory function to identify patients with early dementia is indicated. Such assessment may be significant enough to put the patient at higher risk for postoperative cognitive decline. We therefore propose the following screening test battery to include at a minimum: (1) a memory symptom checklist (with patient and caregiver), (2) MMSE (to rapidly screen for major problems in cognitive skills), (3) a superspan memory test (ie, the 10-item shopping list), and (4) a neurobehavioral assessment to detect the presence of major depression and other significant behavioral disturbances (ie, Neuropsychiatric Inventory or Beck Depression Inventory). If abnormalities are detected, then more complete neuropsychological testing should be performed to rule out dementia.

Depression is a frequent psychiatric symptom that accompanies PD, occurring in an estimated 40% of patients. In our series, no patient experienced major depressive illness but 41% exhibited mild depressive symptoms. Following surgery, there was an overall improvement in the Beck Depression Inventory scores. Improvements in depression following VPP may be secondary to psychological factors resulting from improved motor function, alterations in basal ganglia circuitry, and/or adjustments of antiparkinson medications. Most investigators agree that both psychological and biological components play an etiologic role in the depression manifested by individuals with PD. Moreover, levodopa therapy can also influence depression in individuals with PD and monoaminergic and serotonergic deficiencies may underlie these symptoms. The effect of VPP on local neurochemical circuitry function is unknown.

Most patients experienced beneficial relief of their parkinsonian motor symptoms following unilateral VPP and balance also tended to improve. Overall cognitive and behavioral processes were not adversely affected by VPP in cognitively intact patients. One measure of higher executive functioning, category fluency, worsened slightly but did not result in any functional impairment. Patients with a borderline preoperative cognitive performance, however, may be at risk for postoperative mental decline.

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