Effect of Pallidotomy on Postural Control and Motor Function in Parkinson Disease

Marsha E. Melnick, PhD; Glenna A. Dowling, PhD; Michael J. Aminoff, MD, FRCP; Nicholas M. Barbaro, MD

Objective: To investigate the effects of pallidotomy on postural reactions and other motor parkinsonian deficits.

Design: Comparison of performance by patients before and after pallidotomy on tests of balance and function.

Setting: A Parkinson disease Center of Excellence and Center for Human Performance Testing at a university hospital and research center.

Participants: Twenty-nine patients with Parkinson disease undergoing pallidotomy.

Main Outcome Measures: Performance results on the United Parkinson's Disease Rating Scale (UPDRS), activities of daily living and motor subscales (parts II and III), and posturography (sensory organization test), which were collected before and 3 and 6 months after surgery with patients in the practically defined off state (medication withheld for at least 12 hours).

Results: Data were analyzed with a paired Wilcoxon and Spearman correlation. There was a significant improvement in mean ± SD UPDRS motor subscale score after pallidotomy (before surgery, 52.43 ± 13.46; after surgery, 43.93 ± 15.15; z = 3.63; P = .003). There were no significant changes in the UPDRS activities of daily living subscale or average stability scores when the group was examined as a whole. However, examination of individual data revealed that 9 (56%) of 16 patients who could stand independently before surgery showed improvement in either the number of falls or the average stability score. No patient who was unable to stand independently before surgery was able to stand independently after it.

Conclusion: Pallidotomy helped improve overall motor function in patients with parkinsonism and, for some patients, also improved postural stability.

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Pallidotomy has been used to improve the symptoms of Parkinson disease (PD) when use of medications is ineffective or leads to disabling adverse effects. Pallidotomy is reported to improve rigidity and bradykinesia, and to decrease levodopa therapy–induced dyskinesias and tremor. However, the effect of pallidotomy on postural stability, another major cause of parkinsonian disability, has not been extensively studied.

Postural control involves the integration of sensory signal processing from the visual, proprioceptive, and vestibular systems, with selection and subsequent generation of an appropriate motor response. Patients with PD have abnormalities in the latency and amplitude modulation of postural reflexes. Several investigators found patients with PD to have an increased dependence on visual information to maintain an upright posture compared with healthy subjects. The role of vestibular dysfunction in the postural instability of PD is uncertain; such abnormalities have rarely been found. Subtle defects in proprioceptive function have also been noted in some instances. In addition to the motor and sensory components of postural control, there are biomechanical requirements for postural stability. In an extensive evaluation of 11 healthy elderly subjects, Toole et al found that peak torque generation at the knee and ankle is important in the maintenance of stability. A full range of motion at the ankle is necessary for good balance. These mechanical factors, which are important for postural control, are impaired in many patients with PD.

One aspect of normal upright posture, termed “steadiness,” is the ability of a person's center of gravity to fluctuate incessantly, traversing large total excursion...
PATIENTS AND METHODS

PATIENTS

Forty-three consecutive patients with idiopathic PD who were scheduled for pallidotomy participated in this study and were tested before surgery. Patients with any additional cause of gait or balance abnormality—neurologic or orthopedic—were excluded, as were those with supranuclear palsy or Parkinson plus syndrome. Of patients included in the study, 2 subsequently had strokes (1 secondary to a hemorrhage during pallidotomy, and the other from a stroke 2 months after pallidotomy), 3 died (1 from aspiration pneumonia 2 weeks after pallidotomy, and 2 from unrelated causes during follow-up), 5 did not attend follow-up visits, and 4 violated protocol by taking medication just before the postpallidotomy evaluation. Therefore, data before and after pallidotomy were collected on 29 patients who were between stages II and V on the Hoehn and Yahr scale (mean ± SD, 3.25 ± 0.76). All patients voluntarily signed an informed consent form approved by the internal review board of the University of California at San Francisco. Mean ± SD age of all patients for whom data before and after pallidotomy were collected (17 men and 12 women) was 66.4 ± 9.4 years. No patient had any features to suggest an atypical or secondary parkinsonian syndrome, and all responded to dopaminergic therapy.

TEST PROCEDURE

Patients were tested during the week before surgery and again 3 to 6 months after surgery at their regular follow-up visit. They were tested after medication had been withheld for at least 12 hours—the practically defined off state—so that the evaluation before and after pallidotomy would be unaffected by any changes in medication requirements or response to therapy that might have followed surgery. Patients took their last dose of medication the evening before testing and then omitted further medication use until testing was completed. All tests were performed at the same time of day before and after pallidotomy. Despite the fact that some effects of levodopa therapy continue beyond 12 hours, this protocol was the most practical way to control for the effects of medication.

Patients were tested using posturography (Smart Balance Master software version 4.3; Neurocom International Inc, Clackamas, Ore) using the sensory organization test. Test-retest reliability and face validity are well established. Body sway was measured during differing sensory conditions that alter the visual and proprioceptive input by eliminating vision or introducing incorrect information about the position of the ankle, peripheral visual field, or both. There were 3 conditions with a stable platform and 3 conditions in which the platform moved in response to the patient’s sway pattern. For each platform condition, patients stood with eyes open, eyes closed, and a visual surround that moved in response to sway (Table 1). Following the standardized protocol, patients were tested once for conditions 1 and 2, and 3 times for conditions 3 through 6, for a total of 14 trials.

Sway was computer-calculated based on the vertical ground reaction forces transmitted through the patient’s feet, and recorded by dual force plates in the base of the platform. Sway is reported in both angular degrees and as a percentage stability score. Percentage score was calculated based on a cone from the feet to the head. This represents a person’s absolute maximum limit of available sway, as determined by the patient’s height and base of support, with the feet side by side and shoulder-width apart. This score indicates how close the patient is to falling. A score of 100% means that the person demonstrates no sway (and therefore has 100% of the cone’s area left in which to sway); 0% is recorded when the person has swayed to the limits of the cone (and therefore has to step to avoid a fall, or does fall). The percentage stability score calculated is based on a normative value of maximum stability established after extensive testing by the manufacturer. Mean maximum stability of all 14 trials is averaged to yield an average stability score.

During testing, patients were placed in a protective harness to prevent falls. Mean average stability score for conditions 1 through 6 (Table 2) was 7.6 ± 6.1% for conditions 1 and 2, and 6.9 ± 5.6% for conditions 3 through 6, for a total of 14 trials.

Scores for each variable, before and after surgery, for the entire sample and for only those patients who could stand independently for 20 seconds are presented in Table 2. There was a significant improvement in UPDRS motor subscale score after surgery (\(P < .001\)). There were no significant changes in ADL subscale score (\(P = .10\)) or in average stability score (\(P = .23\)). As expected, there was a significant negative correlation (\(r = -0.51; P = .011\)) between UPDRS motor score and average stability score: patients with a lower (ie, better) motor score had a higher percentage maximum stability score. No patient who was unable to stand independently before surgery was able to stand independently after surgery. Seven patients (24%) improved in either the number of falls or the average stability score, 18 (62%) had no change, and 4 (14%) worsened. Scores for the postural stability item on the UPDRS motor subscale indicated that 3 patients (10%) im-
the 6 conditions and number of falls that would have occurred but for the harness were recorded for each test condition. Patients who fell on the first trial or could not stand for 20 seconds independently were given an average stability score of 0%. This allowed all patients to receive a score, even those who could not stand for 20 seconds before surgery, thereby ensuring presurgery and postsurgery comparative data.

All patients were also assessed using the United Parkinson’s Disease Rating Scale (UPDRS) activities of daily living (ADL) and motor subscales (parts II and III). The score for the postural stability item (part III, item 43) on the UPDRS was separated out for further correlational studies. The examiner (G.A.D.) for the UPDRS was different from the examiner (M.E.M.) for the balance tests; the 2 did not compare results during data collection.

Stereotaxic pallidotomies were performed using the Leksell stereotactic frame and positive contrast ventriculography for localization. The target chosen was 18 to 22 mm lateral, 4.5 to 5.5 mm inferior, and 2.0 to 2.5 mm anterior to the midcommissural point. Administration of antiparkinsonian medications was discontinued the night before the procedure, and patients received little or no sedating medications during the procedure. Electrical stimulation was used to help guide lesion location. If patients experienced phosphenes during stimulation (<4 mA at 20 Hz), indicating proximity to the optic tract, the electrode was moved dorsally and, sometimes, laterally. If motor activity occurred (<4 mA at 1 or 20 Hz), indicating proximity to the internal capsule, the electrode was moved laterally. During lesioning, patients were monitored for motor, speech, and visual functions. Between 1 and 4 lesions (usually 2 lesions) were made until adequate reversal of the patient’s preexisting parkinsonian features was seen. The first lesion was made with a radiofrequency probe (Radionics Inc, Burlington, Mass) having a 3-mm exposed tip. Subsequent lesions were made with a probe having a 3-mm exposed tip.

Magnetic resonance images were obtained 6 months after surgery to determine lesion location and size. This measurement should reflect final effective lesion characteristics and should not include temporary changes such as surrounding edema. A coronal high-resolution fast spin-echo image and T1 axial fast spin-echo were used to provide images of the basal ganglia. Lesions were measured with calipers and compared with the ruler size associated with the image being measured. All measurements were made by a neuroradiologist who was unaware of the patient’s clinical status. Lesion height was measured from coronal sections, lesion width was determined by the average of the widest dimension on coronal and axial images, and anteroposterior dimension was measured from the axial image with the largest lesion. The globus pallidus was arbitrarily divided into 9 sections based on its 3-dimensional size (medial, middle, and lateral sections in the mediolateral plane from axial and coronal scans; dorsal, middle, and ventral sections in the dorsoventral plane from coronal scans; and anterior, middle, and posterior sections in the anteroposterior plane from axial scans). Lesion location was judged to be in the middle or ventral sections in the dorsoventral plane, in the middle or posterior sections in the anteroposterior plane, or in any mediolateral sections, provided the lesion did not extend outside the globus pallidus in that plane.

**DATA ANALYSIS**

Analyses were performed for all patients (N = 29) and for those who could complete the sensory organization test, ie, stand independently for 20 seconds (n = 16). A Spearman rank correlation coefficient was used to test the correlation between the UPDRS postural stability score on part III and the overall score on the sensory organization test, and between the UPDRS postural stability score and the total number of falls. Changes in the number of falls, average percentage maximum stability score, and UPDRS scores before and after pallidotomy were examined using a paired Wilcoxon test. Lesion site and change in UPDRS motor subscale score were tested with a χ² analysis based on whether the lesion was in the globus pallidus and then on the location of the lesion within the globus pallidus (anteroposterior and dorsoventral).

**COMMENT**

Our results agree with those of other investigators, who found improvement after pallidotomy based on the UPDRS motor subscale score. However, we did not find significant improvement in postural stability. Most patients had no change in the UPDRS postural stability item, number of falls, or average stability after pallidotomy. This finding is in contrast to 3 studies that found improved postural stability after pallidotomy but in accord
with other studies\(^2\)-\(^8\) that found unchanged postural stability or gait.

We found no significant improvement in the UPDRS ADL subscale scores after pallidotomy. The apparent discrepancy between improvement on the motor subscale but not the ADL subscale of the UPDRS may reflect differences in the assessment process. In our study, the ADL subscale reflected patients' subjective self-assessment of their best level of functioning. In contrast, the motor subscale is an objective assessment of the patient in the off stage, and was performed by a trained clinician (G.A.D.) in our experimental protocol. It thus seems that in our study, pallidotomy did not change the patients' perception of their best level of function, but did improve motor symptoms in the unmedicated condition. This is in accord with the experience of other investigators. Lozano et al\(^7\) reported significant improvement in ADL function in the off but not the on state after pallidotomy, and other investigators\(^5,7,8\) reported improvement after pallidotomy in response fluctuations or off-state symptoms in patients with advanced PD, but negligible changes in the on state.

Patient expectations might play a large role in their self-evaluation of postoperative outcome. Patients who are less severely affected may have higher expectations for improvement in their best function than those more severely affected. In our patient sample, those with lower UPDRS scores after surgery. It is important, therefore, to develop an assessment tool for patient expectation after surgery.

As reported by other investigators,\(^1,8\) rigidity improved after pallidotomy. This was reflected by a change in the ability of many patients to adapt their balance strategy after surgery. For example, before surgery, 1 patient was unable to shift from an ankle strategy to a hip strategy and would fall when such a shift was necessary. After surgery, he was able to recruit the hip strategy and had fewer falls during testing. However, despite a reduction in rigidity, overall balance ability (ie, average stability score) did not improve after surgery. This finding is in agreement with the view that rigidity is a deficit distinct from postural instability.\(^9,13\) It is possible that the precise motor circuitry for control of muscle tone and speed of movement is separate from that which controls postural adaptations and, therefore, these 2 symptoms may be affected differently by pallidotomy. This idea is supported by the theory that many parallel pathways govern basal ganglial functions.\(^20\) Seven patients had improved balance ability, as reflected by an increased average stability score or decrease in number of falls. This improvement was unrelated to size or location of the surgical lesion in any plane, which is in agreement with the findings of Sutton et al\(^8\) in their study of 5 patients. At the University of California at San Francisco, as at many other centers, pallidotomy is performed without electrophysiologic monitoring by unit recording. The utility of such recording is emphasized by some authors,\(^3,5,7\) but no direct comparisons were made to demonstrate that 1 technique affords superior patient outcome. We are, therefore, not able to discuss differences in cellular electrical activity for patients with and without postural improvement. However, the absence of a correlation between the balance outcome and size or location of the lesion on magnetic resonance imaging suggests that such recording would not explain differences among patients.

We expected a stronger correlation between average stability score and the postural stability item on the UPDRS. The reason for the weak, although statistically significant, correlation may be that the postural stability item is not sensitive enough to detect mild differences between patients, whereas the Smart Balance Master has an ability to assess several postural situations. The insensitivity of the postural stability item may also be the reason for disparity between investigators\(^1,3-5,7,8\) regarding improvement in postural stability after pallidotomy.

Although there were no statistically significant changes in average stability scores for the group as a whole, 9 patients (56%) who were able to stand before surgery showed improvement in the average stability score or a decrease in the number of falls after surgery. Thus, for some patients, pallidotomy resulted in improved pos-

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<th>Table 1. Description of Balance Test Conditions</th>
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<td><strong>Condition No.</strong></td>
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*Sway referenced indicates that the platform moves in response to the patient's sway pattern such that the ankle is kept at 90°.
†Sway referenced indicates that visual surround moves in response to the patient's sway pattern such that the head appears to remain a constant distance from the wall.

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<tr>
<th>Table 2. Assessment Scores Before and After Pallidotomy*</th>
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<td><strong>All Patients (N = 29)</strong></td>
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<td><strong>UPDRS</strong></td>
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<td>ADL subscale</td>
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<td>Motor subscale</td>
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<td>Item 43 (postural stability)</td>
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<td>Average stability score</td>
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*UPDRS indicates United Parkinson's Disease Rating Scale; ADL, activities of daily living. Unless otherwise indicated, values are given as mean ± SD.
tural stability. We could not identify any factor that predicted whether balance would improve. There were no correlations between lesion site or size and change (improvement or worsening) in balance. It is possible that a unilateral surgical procedure has little effect because postural stability requires bilateral postural control. Bilateral pallidotomy is rarely performed, and there are no data on postural stability after this surgery. Several other investigators found no significant improvement in postural stability after unilateral pallidotomy, despite improvement in bilateral functioning. Therefore, our findings suggest that pallidotomy is probably not indicated when postural instability is the patient’s main complaint, although it may lead to mild benefits in some patients.

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Reprints: Marsha E. Melnick, PhD, Graduate Program in Physical Therapy, Box 0736, University of California at San Francisco, San Francisco State University, 1320 7th Ave, San Francisco, CA 94143-0736 (e-mail: mmelnick@sfsu.edu).

REFERENCES