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Five year follow-up of unilateral posteroventral pallidotomy in Parkinson's disease

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Abstract

Background—Neurocognitive outcome research of individuals with Parkinson's disease following unilateral pallidotomy is inconsistent. While some studies reported few cognitive changes, other investigations have more consistently shown both transient and long-term cognitive decline postoperatively.

Methods—We report the long-term motor and neurocognitive outcome 5 years post-surgery for 18 Parkinson's disease patients (12 men and 6 woman; all right-handed) who underwent right or left unilateral posteroventral pallidotomy.

Results—Pallidotomy patients revealed long-term motor benefits from the surgery in their "off' state and control of dopa-induced dyskinesias in their "on" state, which is consistent with previous research. We found mild declines in oral and visuo-motor information processing speed, verbal recognition memory, and mental status 5 years after surgery, which differs from previous literature regarding the long-term neurocognitive outcome following pallidotomy. Differences between the right and left pallidotomy patients for both motor and cognitive skills were not found.

Conclusion—Although deep brain stimulation is presently the treatment of choice, pallidotomy continues to be performed around the world. Consequently, while unilateral pallidotomy should be considered a treatment option for Parkinson's disease patients who suffer from severe unilateral disabling motor symptoms or dyskinesias, the long-term neurocognitive outcome should also be considered in treatment decisions.

Keywords

Parkinson's disease; posteroventral pallidotomy; neuropsychology; cognition

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Unilateral posteroventral pallidotomy is a safe and an effective treatment for the motor symptoms of Parkinson's disease.[3,6–8,10–11,15,17–20,26,29,32,43] Although this ablative procedure has been gradually replaced by deep brain stimulation (DBS), pallidotomy continues

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to be used in countries were the cost of DBS is prohibitive and access to programming is limited. The short-term motor improvements of pallidotomy are well-documented in the literature including reduction in "on" state dyskinesias and "off" state tremor, bradykinesia, gait and postural stability and other Parkinsonian features.[3,5,7,10,20,26,29,34,43] These improvements have been reported to be maintained for up to 2 years following surgery at several centers.[4,9,11–12,25,31,45] In addition, maintenance of some pallidotomy related motor improvements has been documented for up to 4 years following surgery. [1,11,39,42]

Research regarding the short-term neurocognitive changes in individuals with Parkinson's disease following pallidotomy has been variable. While some studies reported few cognitive changes following pallidotomy, [3,30,36–37] other investigations have more consistently shown cognitive changes postoperatively.[1,13,32–33,35,39,40,41] Our research found a transient decline in verbal memory 3 months post-pallidotomy that returned to baseline at the 1 year follow-up.[32] Riordan and colleagues (1997) reported that left pallidotomy patients declined in verbal and semantic fluency, while right pallidotomy patients declined in information processing speed, visuospatial construction, and spatial memory, approximately 5 months post-surgery.[33] Trepanier and associates (1998) reported a decline in verbal learning, verbal fluency, and attentional capacity for left pallidotomy patients at 3 or 6 months post pallidotomy, with their most affected patients still noting cognitive difficulties 2 years post surgery. Their right pallidotomy patients demonstrated a transient decline in spatial memory with an improvement in verbal learning ability over the same time period. [39] The most consistently reported short-term cognitive findings following unilateral pallidotomy are a decline in verbal fluency and a transient decline in verbal memory, particularly for patients who underwent left pallidotomy.

The long-term cognitive outcome of pallidotomy has been reported only preliminarily in small samples of patients in the literature. [1,39] Alegret and colleagues (2003) [1] found no significant differences between a baseline neuropsychological evaluation and a 4-year follow-up evaluation in 11 unilateral pallidotomy patients. Similarly, Baron et al. (2000) reported that 67% of patients who completed a neuropsychological assessment 4 years following pallidotomy showed stable cognitive status as measured by the Mattis Dementia Rating Scale. [4] On the other hand, using the UPDRS, Pal et al. (2000) reported that mental scores 3-years following pallidotomy showed an almost four-fold decline from the 6-month outcome in 15 unilateral pallidotomy patients.[31] Additionally, Hariz et al. (2001) found cognitive decline in 3 of 13 patients at a mean follow-up of 10 years.[15] However, they did not describe how they evaluated the cognitive decline and the specific duration of follow-up for these 3 patients.

It is essential to assess the long-term cognitive outcome of pallidotomy on a comprehensive neuropsychological battery to fully appreciate the overall efficacy of the surgery. We share our experience regarding the motor functioning and neurocognitive performance of 18 patients with Parkinson's disease with a mean follow-up of 5 years following unilateral pallidotomy.

METHODS

Subjects

The inclusion and exclusion criteria for the pallidotomy procedures performed at the Baylor College of Medicine (BCM) Parkinson's Disease and Movement Disorders Center (PDMDC) were reported in detail previously. [1,39] Initially, our sample was comprised of 54 individuals who underwent unilateral pallidotomy (38 left- and 16 right-sided; 31 men and 23 women) and all of these patients were followed on average 6 months and 1 year post surgery. Of our initial sample, 15 participants underwent contralateral pallidotomy and 1 patient underwent contralateral subthalamic nucleus deep brain stimulation; therefore they were not included in these analyses [46]. Of the remaining 26 patients, 2 patients died, 4 were local patients who changed neurologists and terminated both neurological and neuropsychological evaluations at the BCM PDMDC, 19 patients were out-of-state referrals who were only followed for a few months after surgery, and 1 patient continued treatment at BCM PDMDC, but refused to undergo follow-up neuropsychological evaluations, placing our attrition rate at 38%.

We compared demographic, medical and neuropsychological variables between the attrition group (20 patients) and the 18 patients included in this outcome study at baseline and their short-term (average of 5.3 months; SD=2.7 months) evaluation. No significant differences were found on neurological and cognitive variables between the attrition group and the long-term follow-up group. However, a significant difference in age (p=0.01) between these two groups was found. The long-term follow-up group was on average 56.9 (SD=9.44) years old, while the attrition group was 63.4 (SD=9.08) years of age. The older age of the attrition group may have contributed to the lack of participant engagement in the long-term follow-up.

The 18 unilateral pallidotomy patients who were included in the analyses had neuropsychological evaluations at baseline, short-term follow-up (5.3 months; SD=2.7 months; Range 3.0–8.1 months following surgery) and long-term follow-up (5.1 years; SD=1.9 years; Range 2.5–9.8 years). This study was approved through BCM's Institutional Review Board. All pallidotomy patients (12 men and 6 women) were right-handed and had advanced idiopathic Parkinson's disease based on clinical symptoms and neurological examination. Demographic or neurological variables did not significantly differ between the left- and right-sided pallidotomy patients. Two patients who had a previous neurosurgical procedure prior to pallidotomy were included in the analyses to capture a representative sample of pallidotomy patients. One patient had an adrenal implant to the right caudate nucleus nine years prior to his pallidotomy; the second patient had a left frontal ventriculo-peritoneal shunt for hydrocephalus due to aqueductal stenosis, 10 years prior to pallidotomy. Relevant patient characteristics for the individual unilateral pallidotomy patients are presented (Table 1). In addition, a statistical analysis of a subgroup of 10 of the 18 patients who had neuropsychological evaluations at an interim point post pallidotomy (1.3 years; SD=.49; Range .99–2.07) was also conducted to evaluate the rate of cognitive decline among our sample.

Neurological evaluation

Patients were evaluated by movement disorder specialists in their "on" and "off" states using a modified Core Assessment Program for Intracerebral Transplantation Protocol.[28] A detailed description of the neurological evaluations has been presented elsewhere.[23,24]

Neuropsychological evaluation

The neuropsychological test battery was selected to assess the pattern of cognitive deficits previously shown to be impaired in advanced Parkinson's disease. A detailed description of the neuropsychological evaluation has been presented elsewhere.[32] The participants were administered the following measures: Mini Mental Status Exam (MMSE), California Verbal Learning Test (CVLT), Boston Naming Test (BNT), Controlled Oral Word Association Test (COWAT-FAS), Hooper Visual Organization Test (HVOT), Symbol Digit Modalities Test (SDMT), Trail Making Test A & B, Stroop Color Word Test (Stroop), Wisconsin Card Sorting Test (WCST), and Beck Depression Inventory (BDI).

Surgical procedure

Pallidotomy was performed contralateral to the motorically affected side of the body, resulting in a larger number of left-sided surgeries. Stereotactic CT guidance, microelectrode recording and macrostimulation were used to determine the optimal site of the lesion within the internal segment of the globus pallidus (GPi). A detailed description of the procedure has been published elsewhere. [21]

Statistical Analyses

Repeated measures ANOVAs with time (baseline, short-term, long-term follow-up) as the within subjects factor were conducted for the neuropsychological measures and the UPDRS computed scores. Standardized scores, correcting for the influence of age and education were utilized. Non-parametric tests were conducted when analyzing categorical variables. Side of surgery (right vs. left) was included as a between subjects factor in the analyses. However, no significant differences were found for side of surgery. Consequently, all data analyses are reported with the sample as a whole.

RESULTS

Group demographic and medical characteristics of the sample at the baseline evaluation are presented (Table 2). No significant differences were found on demographic variables between right and left pallidotomy patients at baseline.

Neurological Outcome

The neurological data for both “on” and “off” states is reported (Table 3). No significant differences between right and left pallidotomy patients on were found on neurological outcome. Overall, pallidotomy patients demonstrated a significant improvement in their UPDRS motor and total scores in the “off” state at the long-term follow-up. However, the long-term motor scores significantly declined in comparison to the patients’ short-term scores. In contrast, in the “on” state the long-term motor and total UPDRS scores did not differ significantly from the baseline scores in the “on” state, but the short-term follow-up “on” state scores demonstrated a significant improvement from baseline levels. Our patients maintained a limited amount of their motor improvements in the “on” state at the long-term follow-up as measured by the UPDRS motor score. Eighty-nine percent of patients showed motor improvement in the “on” state and 100% of patients showed motor improvement in the “off” state.

Dyskinesias—Patients with right or left pallidotomy showed significant reductions in the duration of dyskinesias at the short-term follow-up, which was maintained at the long-term follow-up ($p = 0.002$ and 0.007, respectively). In addition, they reported dyskinesias less than 25% of the waking day after surgery on long-term follow-up, which was a reduction from 26–50% of the day prior to surgery.

Activities of Daily Living—At the short-term follow-up, ADL scores for both “on” and “off” states showed a significant improvement. However, these scores returned to baseline levels for the “on” state at the long-term follow-up. Our patients showed significant improvements in their ADL scores in the “off” state at the long-term follow-up. While 72% of patients showed improvement in the “on” state, 83% of patients showed improvement in the “off” state.

Neuropsychological Measures

There were no significant differences between the left and right pallidotomy patients over time (Surgery Side X Time); therefore, we report the means (SD) for the whole sample for each of the three time periods (Table 4). Lower scores on neuropsychological measures reflect worse performance, except for Trail Making Test Parts A and B.

Mental Status—Scores on the Mini Mental Status Exam declined significantly from baseline to long-term follow-up [27.4 (3.5) to 24.7 (5.4); $p = 0.01$)]. Post-hoc analysis revealed significant differences between the baseline and the long-term follow-up evaluation ($p = 0.003$) and between the short-term and long-term follow-up evaluations ($p = 0.01$).

Verbal Learning—The discriminability index of the California Verbal Learning Test showed a significant decline over time (p = 0.05). Post-hoc analysis revealed that pallidotomy patients' recognition memory scores declined between the baseline and the long-term follow-up evaluation (p = 0.02) and between the short-term and long-term follow-up (p = 0.01). Verbal learning did not show significant changes between any of the evaluations for total learning (p = 0.59), delayed free recall (p = 0.64) and delayed cued recall (p = 0.21).

Language—Lexical fluency and confrontational naming did not show significant differences across time (p = 0.47; 0.68, respectively).

Visuo-spatial—The main effect of time was non-significant for the Hooper Visual Organization Test (p = 0.16).

Information Processing—The Stroop Word, Stroop Color, Trail Making Test Part A, and Symbol Digits Modalities Test scores declined significantly over time (p = 0.009; 0.008, 0.04, 0.01, respectively). Significant differences were found for these measures from the baseline to the long-term follow-up evaluation (p = 0.05, 0.004, 0.01, 0.003, respectively) and from the short-term follow-up evaluation to the long-term follow-up evaluation (p = 0.008, 0.01, 0.01, 0.006, respectively).

Executive Functioning—Scores on the Wisconsin Card Sorting Test did not change significantly over time for total errors (p = 0.69) or perseverative errors (p = 0.69). The Trail Making Test Part B and the Stroop Color Word scores also did not change significantly over time (p = 0.19, 0.19, respectively).

Mood—Depression as measured by the Beck Depression Inventory did not show a significant change over time (p = 0.21).

Sub-sample Analyses—Scores for a sub-sample of 10 of the 18 patients were examined at 1.3 years post pallidotomy to assess for the progression of neurocognitive decline between the short-term follow-up (5.3 months) and the long-term follow-up (5.1 years). This subgroup was comprised of 8 males and 2 females with an average of 12.6 (2.80) years of education. Their average age was 55.1 (SD=11.3) and they had on average experienced Parkinson's disease for 14.20 (SD=4.69) years. In comparison to the long-term follow-up, significant differences were not found on measures of information processing. These analyses were likely influenced by the small sample size in addition to the large standard deviations between participants. While scores on the MMSE showed a trend toward decline over the 3 time periods post pallidotomy (p=0.08), a significant decline was not found between the short-term follow-up and the interim testing (1.3 years post pallidotomy) nor was it present between the interim testing and the long-term follow-up. However, a significant decline in MMSE scores (p<0.01) in this sub-sample was found between the short-term and the long-term follow-up. In addition, the same pattern of decline was found on the CVLT discriminability measure for this sub-sample, with a significant decline (p=0.01) between the short- and the long-term follow-up. No other changes were found on the additional neuropsychological measures for this sub-sample. Based on these analyses, we concluded that the sub-sample experienced their significant cognitive decline toward the end of the study evaluation period (average of 5.1 years) and not 6 months or 1 year post pallidotomy. This preliminary analysis suggests that the cognitive decline is likely due to the progression of Parkinson's disease on neurocognitive abilities and not necessarily the effects of the surgical procedure. However, the interaction of this medical condition and the surgical treatment can not be examined in this study due to the lack of a control group and warrants further attention.

Summary—Oral and visuo-motor information processing speed, verbal recognition memory, and general mental status declined from baseline to the long-term follow-up and from the short-term to long-term follow-up evaluations. No significant main effects for lesion side or time X lesion side interaction effects were found for any of the neuropsychological measures. Interim findings in a sub-sample of patients suggest that the cognitive decline became more pronounced at least 1.3 years following surgery.

DISCUSSION

On long-term follow-up, we found that Parkinson's disease patients continued to receive motor benefit from unilateral pallidotomy; however, they demonstrated mild neurocognitive declines. Although the primary focus of this investigation was the cognitive outcome of unilateral pallidotomy, a thorough analysis of the cognitive outcome cannot be carried out without a description of the patients' clinical motor functioning. Our findings of improved UPDRS scores in the "off" state and control of dyskinesias in the "on" state five years following unilateral pallidotomy are consistent with previously reported results with shorter follow-up periods. [4,11–12,15,31,42,45] Our patients continued to experience significant clinical benefit from the surgery, particularly in regard to a dramatic reduction in their dyskinesias and improved ADL scores five years following unilateral pallidotomy. Overall, our motor outcome is consistent with the literature. [14,32,39–40,47]

Whereas the patients retained motor benefit, mild neurocognitive declines were found on long-term follow-up, specifically in oral and motor information processing speed, verbal recognition memory and general mental status. These cognitive declines experienced by our patients 5 years post-pallidotomy are not entirely consistent with the neuropsychological profile associated with the progression of Parkinson's disease. Cognitive changes associated with Parkinson's disease include declines in frontal lobe functioning, including the Wisconsin Cart Sorting Test, Trails B and the Stroop, verbal memory, information processing speed, and verbal fluency. While the decline in information processing speed is consistently associated with a diagnosis of Parkinson's disease and is not an unexpected finding, we did not find the expected declines in verbal fluency and memory as reported in previous studies including Alegret and colleague's (2003) 4-year cognitive outcome study. [1] Consequently, further analyses are warranted to examine the relationship between age, disease progression and unilateral pallidotomy at long-term follow-up. Moreover, the lack of significant findings by lesion side and declines in general mental status and recognition memory suggest a more generalized cognitive decline 5 years following surgery rather than a decline related specifically to the surgical intervention.

Significant differences were not found on measures of information processing for a sub-sample of 10 of the 18 patients at an interim period (1.3 years post pallidotomy). However, scores on the MMSE and on the CVLT discriminability measure showed a significant decline between short and long-term follow-up. Results suggest that the sub-sample experienced their significant cognitive decline toward the end of the study evaluation period and not 6 months or 1 year post pallidotomy. This preliminary analysis indicates that the cognitive decline is likely due to the progression of Parkinson's disease and not their surgical intervention.

Individual MMSE scores at long-term follow-up suggest that one third (6/18) of the pallidotomy patients reached the cut-off for dementia (MMSE<23). Overall, our unilateral pallidotomy sample lost 3 points on the MMSE from the baseline to the 5-year follow-up evaluation. Second, all of the information processing speed measures administered showed declines at the long-term follow-up; both oral and visuomotor information processing speed were impaired. Patients showed increased bradyphrenia, which may be due to the progression of the disease over time or may be a long-term consequence of the surgery. The interplay between the disease and the sequelae of unilateral pallidotomy was not investigated due to the lack of a comparison group. A pallidotomy surgery wait list group matched on age, educational attainment and disease duration would provide us with a better understanding of the impact of the surgery on both motor and neurocognitive abilities. However, it would be difficult, if not impossible and unethical, to maintain a long-term, matched comparison group given the efficacious surgical treatments available to individuals with Parkinson's disease currently.

Several studies have reported that age may be a confounding factor in the cognitive outcome of pallidotomy, with older patients at time of surgery performing worse on neuropsychological outcome than younger patients. [4,39,41] Our patients were on average 57 years old at the time of surgery, with only 2 patients being over 70. The two older patients' performance was consistent with the remaining unilateral pallidotomy sample. Due to the small sample size of older patients, we were unable to analyze independently the role of age in our cognitive outcome. However, our findings of cognitive decline in our young sample suggest that age cannot be the only factor resulting in cognitive decline following pallidotomy. It should be noted that patients who were lost to follow-up were significantly older than our sample. Consequently, the influence of demographic variables must be considered.

The long-term cognitive declines found in the current study suggest a further progression of the disease affecting frontostriatal circuits. While pallidotomy interrupts the “motor” neural circuitry believed to be responsible for the abnormally patterned motor activity in Parkinson’s disease, our findings suggest that cognitive dysfunction following pallidotomy may be a consequence of disruption in not only the primary motor circuit but a number of interconnected pathways from the basal ganglia to the cortex.[27] Specifically, dopamine depletion in the lateral orbitofrontal and the dorsolateral prefrontal circuits has been suggested as a possible mechanism of cognitive impairment in Parkinson’s disease and may be affected by pallidotomy.[2,38] However, dopamine depletion in the nigrostriatal pathways and in the ascending pathways from the ventromedial tegmentum.[2,38] may not be the only pathways involved in non-motor functioning of Parkinson’s disease patients, but non-dopaminergic systems may also play an important role. [27] Future longitudinal neuroimaging studies may be able to provide additional information as to the mechanism of action for the reported long-term cognitive decline following pallidotomy.

Limitations

Several methodological issues complicate interpretation of this study. First, our sample size is relatively small, thus limiting our power to detect significant differences. Additionally, the small sample size limited our ability to conduct additional statistical investigations of subgroups of patients (e.g., age). Second, our attrition rate for the long-term follow-up was 38%, which is moderately high. We were able to account for the patients who were lost to follow-up and the majority of these patients were unable to return for testing because they were from out-of-state or had changed neurology clinics. Only one local patient who was followed by BCM PDMDC refused to complete further neuropsychological testing. In addition, our attrition group was significantly older than our long-term follow-up sample. The older age of the attrition group likely contributed to their lack of long-term follow-up. Third, the lack of a comparison group limited our ability to make conclusive statements regarding the effects of the progression of Parkinson’s disease on neurocognitive abilities and its interaction with the surgical procedure.

In summary, our results suggest that patients who underwent unilateral pallidotomy continued to receive long-term motor benefits from the surgery, while showing only mild neuropsychological declines. Although currently deep brain stimulation has become the primary treatment choice for patients with Parkinson’s disease, the procedure and subsequent follow-up evaluations can be cost prohibitive. [15] Pallidotomy is still widely performed in many parts of the world because it is effective, much less costly, and does not require extensive follow-up evaluations. In these cases, unilateral pallidotomy should be considered a treatment option for Parkinson's disease patients who suffer from severe unilateral disabling motor symptoms or dyskinesias. However, patients should be counseled as to the potential long-term cognitive risks of the procedure to make an informed decision.

Abbreviations

H&Y, Hoehn and Yahr; GPi, globus pallidus internus; UPDRS, Unified Parkinson's Disease Rating Scale.

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Table 1

Individual Baseline Characteristics of Unilateral Pallidotomy Patients (n=18)

PT	Age	Gender	Educ (yrs)	Hand	H&Y On	H&Y Off	Duration (yrs)	Surgery Side	Short-term Follow-up (mos)	Long-term Follow-up (yrs)
1	40	M	12	R	3	4	11	L	6.9	9.0
2	50	M	12	R	2.5	4	20	L	6.5	6.0
3	51	F	13	R	3	4	23	L	7.4	9.8
4	69	M	8	R	3	4	12	R	3.0	3.0
5	56	M	12	R	2	5	2	L	4.9	3.0
6	36	M	12	R	3	4	10	R	3.6	3.0
7	63	F	12	R	3	4	12	L	3.0	3.2
8	54	M	16	R	2	3	15	L	4.0	3.7
9	62	M	16	R	3	5	15	L	6.1	9.3
10	58	F	14	R	3	4	21	L	3.6	3.0
11	58	F	16	R	2.5	4	12	L	7.1	9.0
12	62	F	14	R	4	5	12	R	3.1	3.8
13	53	M	12	R	2	4	15	R	8.1	8.0
14	70	M	16	R	2	4	19	L	8.0	2.5
15	49	M	16	R	2	3	14	L	3.0	6.0
16	61	M	9	R	3	4	17	L	6.6	4.2
17	70	M	12	R	4	4	10	L	3.1	3.5
18	62	F	12	R	2	5	15	R	3.9	6.2

Table 2

Group Demographics for Right and Left Unilateral Pallidotomy Patients

	Pallidotomy Group		
	Right (n=5)	**Left (n=13)**	**Total (n=18)**
Gender (M%/F%)	60/40	69/31	67/33
Age (yrs)	56.4 (12.7)	57.1 (8.5)	56.9 (9.4)
Education (yrs)	11.6 (2.2)	13.5 (2.3)	13.0 (2.4)
Age of Onset (yrs)	43.6 (12.0)	42.5 (10.3)	42.8 (10.4)
Duration (yrs)	12.8 (2.2)	14.7 (5.6)	14.2 (4.9)
H&Y "on" (Median)	3.0 (Range 2–4)	3.0 (Range 2–3)	3.0 (Range 2–4)
H&Y "off" Median)	4.0 (Range 4–5)	4.0 (Range 3–5)	4.0 (Range 3–5)

Table 3

Neurological Outcome on Short and Long-Term Follow-up for Unilateral Pallidotomy Patients (n=18)

Measure	Baseline Mean (SD)	Short-term Follow-up^ Mean (SD)	Long-term Follow-up+ Mean (SD)	p
H & Y Staging (I–V)				
“On”	2.5 (2–4)	2.0 (0–4)	2.5 (0–4	.002*
“Off”	4.00 (3–5)	3.0 (2–5)	3.0 (2–5)	.001*
UPDRS Total (0–199)				
“On”	49.2 (9.2)	27.4 (12.4)	43.1 (22.6)	.001*
“Off”	93.9 (13.6)	58.8 (14.8)	70.9 (18.0)	.001*
UPDRS Motor (0–144)				
“On”	32.2 (7.1)	17.9 (9.4)	27.3 (14.8)	.001*
“Off”	58.3 (10.4)	37.2 (10.3)	44.3 (12.4)	.001*
UPDRS ADL (0–51)				
“On”	15.6 (4.5)	9.1 (3.2)	14.3 (7.3)	.001*
“Off”	31.6 (3.7)	19.2 (4.7)	23.8 (6.8)	.001*
UPDRS Dyskinesias				
Duration (Median)	2.0 (Range 1–3)	1.0 (Range 0–2)	1.0 (Range 0–4)	.001*
Disability (Median)	2.0 (Range 1–3)	0.5 (Range 0–2)	0.5 (Range 0–4)	.001*

ADL=activities of daily living; H&Y=Hoehn and Yahr Staging, higher number indicates more impairment; UPDRS=United Parkinson’s disease Rating Scale, higher number indicates more impairment.

* p<.01;

^ Mean = 5.3 months; SD = 2.7 months;

+ Mean = 5.1 years, SD = 1.9 years

Table 4

Short and Long-Term Neuropsychological Outcome for Unilateral Pallidotomy Patients (n=18)

Measure	Baseline Mean (SD)	Short-Term Follow-up^ Mean (SD)	Long-Term Follow-up+ Mean (SD)	p
Mental Status				
MMSE (0–30)	27.4 (3.5)	27.3 (3.1)	24.7 (5.4)	**.01**↓
Verbal Learning				
CVLT Total 1–5(0–80)	37.4 (8.4)	35.1 (11.9)	35.8 (14.9)	.59
CVLT Long Delay (0–16)	7.50 (2.7)	7.6 (3.9)	6.80 (4.8)	.63
CVLT Discriminability	89.0 (7.9)	84.3 (22.0)	83.6 (13.8)	**.03**↓
Language				
BNT (0–60)	51.6 (9.3)	52.8 (7.4)	53.4 (6.6)	.68
COWAT-FAS	29.1 (12.6)	27.8 (14.1)	26.6 (17.2)	.47
Visuospatial				
Hooper (0–30)	22.8 (5.6)	23.7 (4.9)	21.7 (7.7)	.16
Info. Processing				
SDMT	37.6 (14.7)	36.8 (16.2)	30.8 (19.3)	**.01**↓
Trails A	53.3 (30.9)	52.3 (32.4)	86.2 (70.8)	**.04**↓
Stroop Word*	74.9 (24.2)	76.2 (23.8)	61.4 (30.8)	**.009**↓
Stroop Color*	54.1 (14.9)	54.4 (15.0)	41.0 (21.1)	**.008**↓
Executive Functions				
Stroop Color Word	28.7 (11.6)	28.8 (10.2)	22.4 (16.6)	.18
Trails B	181.2 (168)	162.5 (107)	188.5 (106)	.18
WCST Total Errors	56.7 (19.4)	52.8 (26.0)	48.0 (28.0)	.69
WCST Persev Errors	30.9 (17.5)	28.3 (18.0)	34.1 (24.2)	.69
Affective Functioning				
BDI (0–63)	9.8 (7.2)	7.7 (6.0)	10.5 (6.5)	.21

Bold=Significant contrasts with significant Time main effect ($p<.05$);

↓=Decline.

^Mean = 5.3 months, SD = 2.7 months;

+Mean = 5.1 years, SD = 1.9 years

*Stroop Word and Stroop Color Word=number of items read within a 45 second time interval; CVLT=California Verbal Learning Test, Trials 1–5, Long Delay; Stroop=Stroop Color Word Test, Interference; WCST=Wisconsin Card Sorting Test, Total Errors.