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72

Does Thalamotomy Alter the Course of Parkinson's Disease?

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Irving Cooper (3) observed that unilateral Parkinson's disease seemed less likely to progress to the other side of the body after thalamotomy that abolished contralateral tremor and rigidity, an effect that he felt might be the result of either the surgery itself or the slow progression of that particular patient's disease. In 1968, Scott et al. (16) reviewed 72 of Cooper's patients who had undergone thalamotomy for unilateral tremor and rigidity before 1963 and found that the disease had progressed to the opposite side in 33% of both the 39 with incomplete and the 33 with complete postoperative relief of contralateral tremor and rigidity. Matsumoto et al. (10) resurrected the notion that surgery might influence the progress of Parkinson's disease, reporting that 48.4% of 64 patients undergoing unilateral, and 63.6% of 22 undergoing bilateral thalamotomy between 1964 and 1969 did not progress after completion of surgery up to the time of their review in 1981, and Miyamoto et al. (11) reached similar conclusions. The possibility that deprenyl (25) might slow or arrest the course of Parkinson's disease has again focused interest on the long-term course of the disease. Because the Toronto Hospital's series of patients with Parkinson's disease undergoing thalamotomy included 55 operated on bilaterally (9), with follow-ups as long as 24 years, we decided to reexamine the issue of progress of the disease after thalamotomy, reasoning that if surgery exerted any effect on progress, first, that surgery would have to be directed toward both sides of the body afflicted with the disease, and, second, it would have to be "successful" in eliminating the features of the disease to which it was directed—tremor and rigidity.

METHODS

Patient Selection

In addition to the 55 patients who underwent bilateral thalamotomy performed by one of us (RRT), a further 31 patients were selected who underwent only unilateral thalamotomy in the same time period as the patients operated on bilaterally, performed in the same manner. Fifteen of these constituted all our patients in that time period who suffered from postencephalitic or youthful (<40 years) onset (PEY) disease. The remaining 16 suffered from idiopathic (non-PEY) disease; these patients had a thalamotomy done within 3 months of the first procedure on the 55 subjects operated on bilaterally and whose postoperative follow-up was 5 years or more.

Between 1961 and 1987, using previously published techniques (21–24), lesions were made with either radiofrequency current or a cryoprobe utilizing liquid nitrogen in what we believed to be nucleus ventralis intermedius of the thalamus after localization with positive contrast ventriculography and macrostimulation (21–23); in a smaller number of more recent cases, computed tomography, microelectrode recordings, and microstimulation (24) were used instead.

Clinical Assessment

All clinical evaluations were made by the same person (RRT) using a standard semiquantitative assessment on a 0 to 5 scale (0 being normal). This was done preoperatively and at intervals postoperatively, with a final follow-up in 1988 where possible, either in the office or in the patient's place of residence. Tremor and rigidity during simultaneous contralateral hand patting (to eliminate the effects of differing degrees of arousal on rigidity) were graded 0 to 5 for each direction of movement for each limb joint on each side of the body, and mean 0 to 5 grades for tremor and rigidity were then determined for each side. Mean 0 to 5 scores for manual dexterity for each side were determined from the scores for handwriting and for repetitive rapid hand patting, supination–pronation of the wrist, touching each finger in succession with the thumb, and finger–nose touching. Mean 0 to 5 scores for locomotion were derived from assessing the acts of rising from a chair, walking in the open and among obstacles, turning in both directions, standing on each leg alone, and performing the Romberg and tandem gait tests. Facial expression and speech were similarly rated. Each patient was graded 0 to 5 on the Matsumoto modification (10) of the Hoehn and Yahr (4) scale (see Table 1). The resulting grading for each patient was then plotted graphically (see Figs. 1 to 8).

Most of the perioperative assessments predated the use of L-DOPA, as shown in Figs. 1 to 8 on which drug therapy is also charted; otherwise examinations were done 3 hours or more after the last dose of L-DOPA, a full drug holiday for each assessment being impractical. Slow-release medication was not used by any of these patients.

Criteria for Postoperative Stability

The study required that criteria be developed for lack of disease progress (stability) after surgery and for degree of success of surgery (relief of tremor and rigidity).

Because our assessment was semiquantitative and therefore subject to some variability, we selected the following criteria for postoperative stability:

1. Follow-up after last surgery of 5 years or longer.
2. No fall in Matsumoto modification of Hoehn and Yahr grade (10) over entire follow-up.
3. Deterioration in the algebraic sum over the entire follow-up of the 0 to 5 ratings for right-

TABLE 1. *Grading of Parkinson's disease*

Hoehn and Yahr (4)	Matsumoto et al. (10)	Clinical description
	Normal	No evidence of disease
1	I	Unilateral involvement only; usually no functional impairment
2	IIa	Bilateral involvement but predominantly on one side; no axial syndrome; self-sufficient in ADL[a]
3	IIb	Moderate bilateral involvement; moderate bradykinesia; positive axial syndrome; restricted in ADL, partially self-sufficient
4	III	Marked involvement; severely disabled in ADL; still able to walk and stand unassisted
5	IV	Confined to bed; marked vegetative and psychological changes

[a]ADL, activities of daily living.

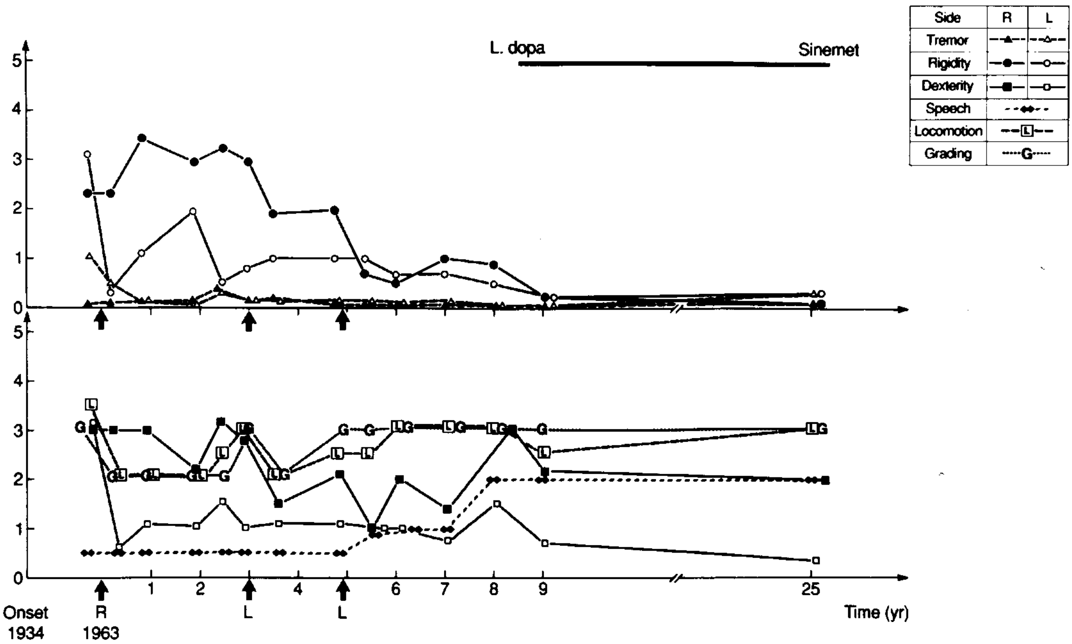

FIG. 1. Patient 53: postencephalitic, onset age 16, bilaterally "successful" surgery, stable over 20 years. Chart displays 0–5 grading of various features of Parkinson's disease (see box) throughout years of follow-up in patients undergoing thalamotomy. Symbols R and L indicate timing of right and left procedures. Therapy with L-DOPA indicated above.

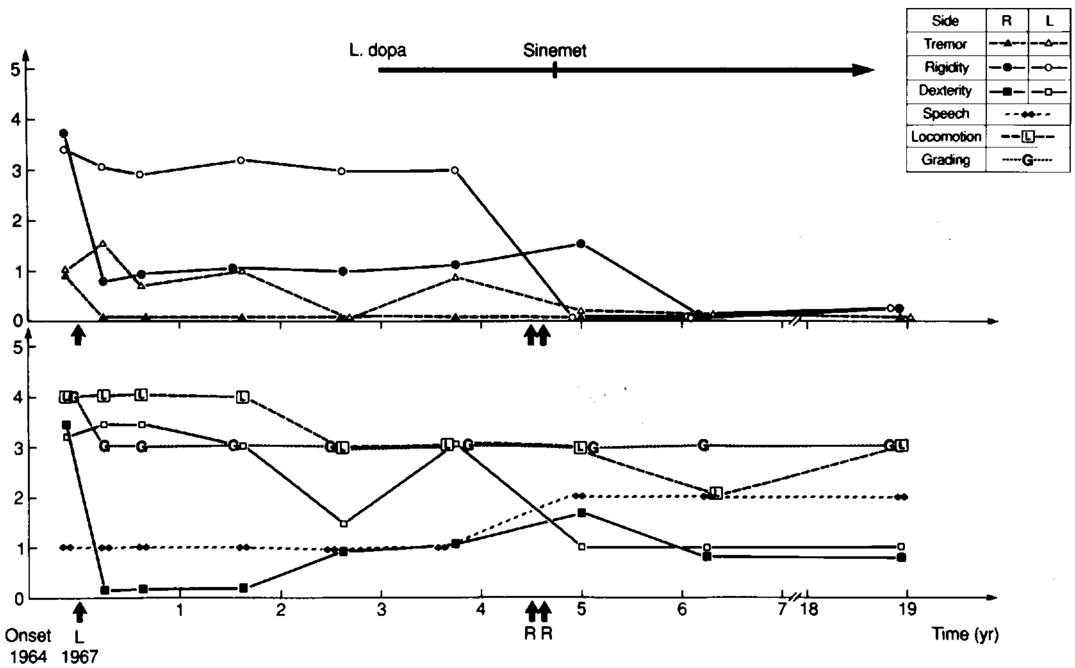

FIG. 2. Patient 38: postencephalitic, onset age 20, bilaterally "successful" surgery, stable over 14½ years. For explanation, see legend to Fig. 1.

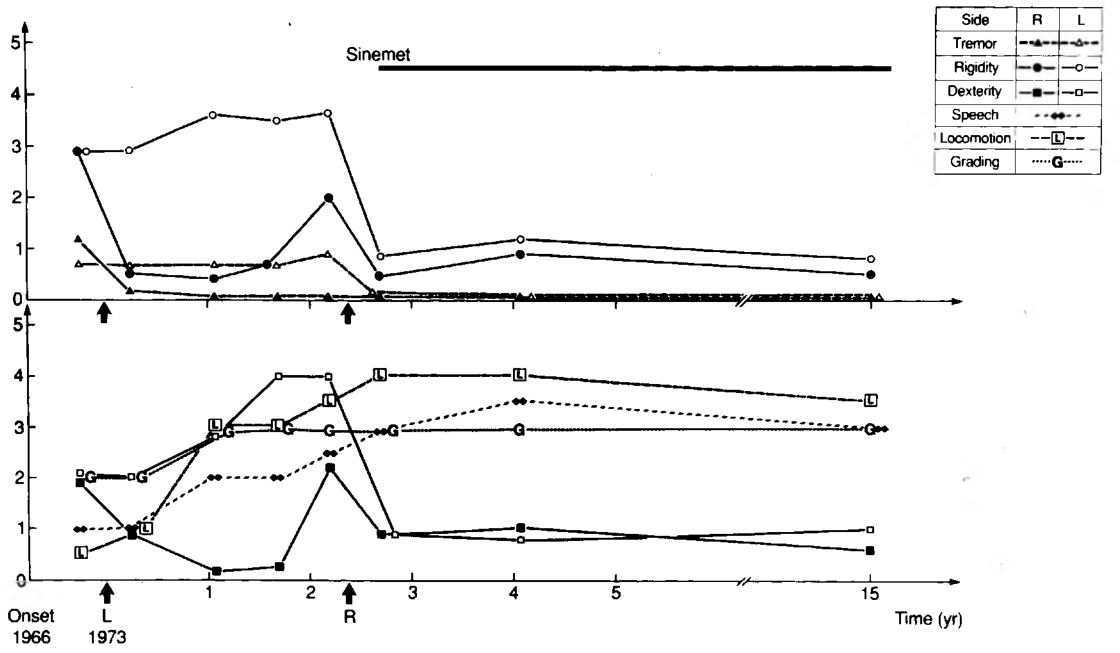

FIG. 3. Patient 44: idiopathic, onset age 43, bilaterally "successful" surgery, stable over 12½ years. For explanation, see legend to Fig. 1.

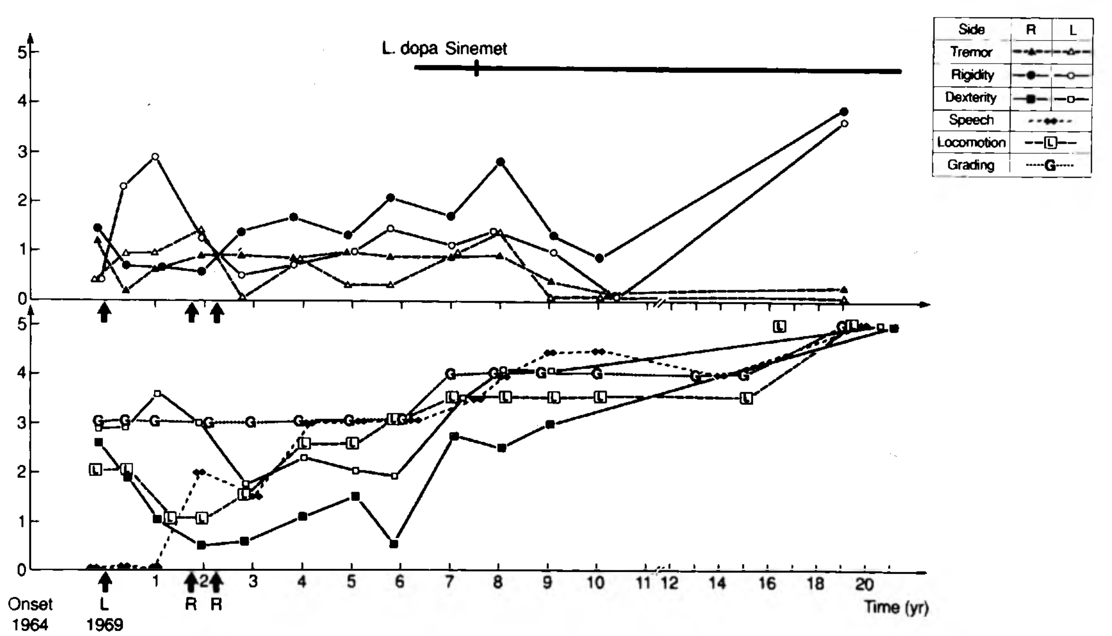

FIG. 4. Patient 6: idiopathic disease, onset age 41, bilaterally "unsuccessful" surgery, unstable. For explanation, see legend to Fig. 1.

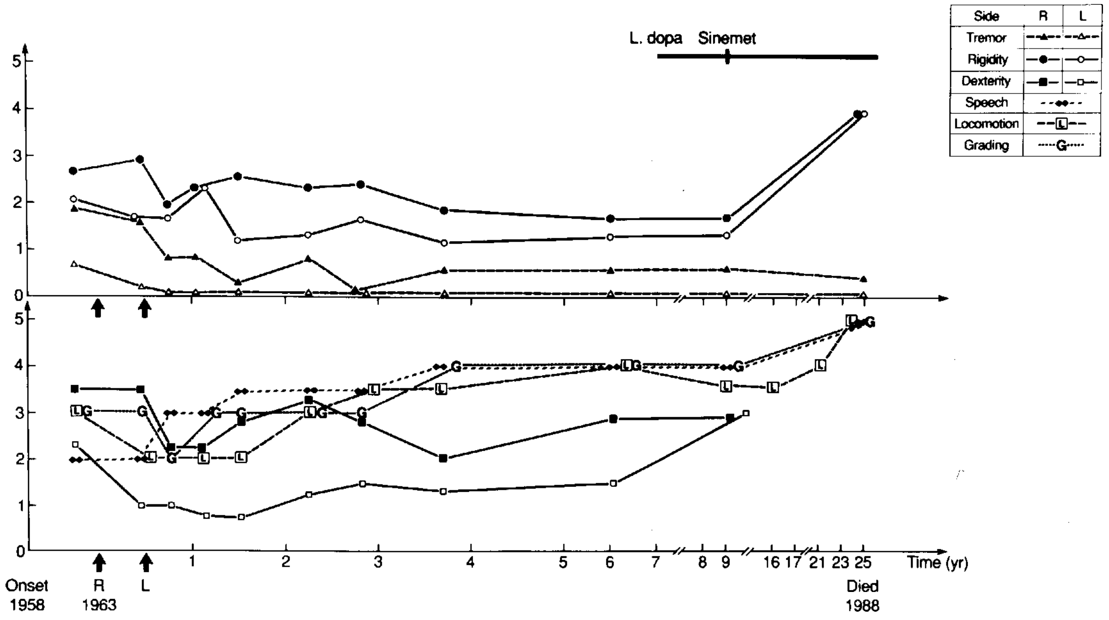

FIG. 5. Patient 5: familial idiopathic disease, onset age 51, bilaterally "unsuccessful" surgery, unstable. For explanation, see legend to Fig. 1.

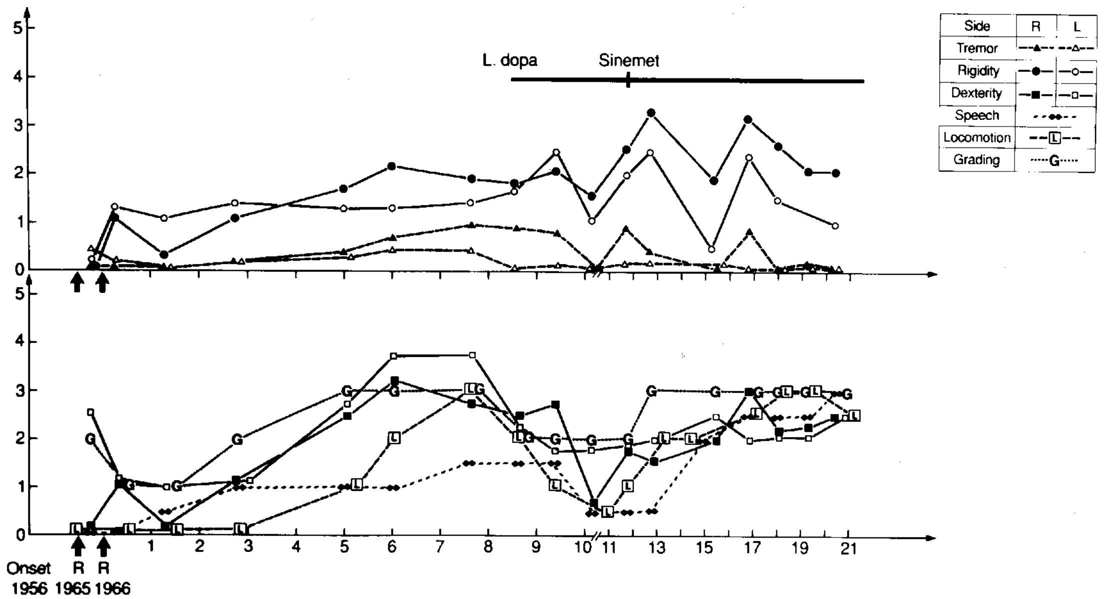

FIG. 6. Patient S: Postencephalitic disease, onset age 37, unilaterally "unsuccessful" surgery, unstable. For explanation, see legend to Fig. 1.

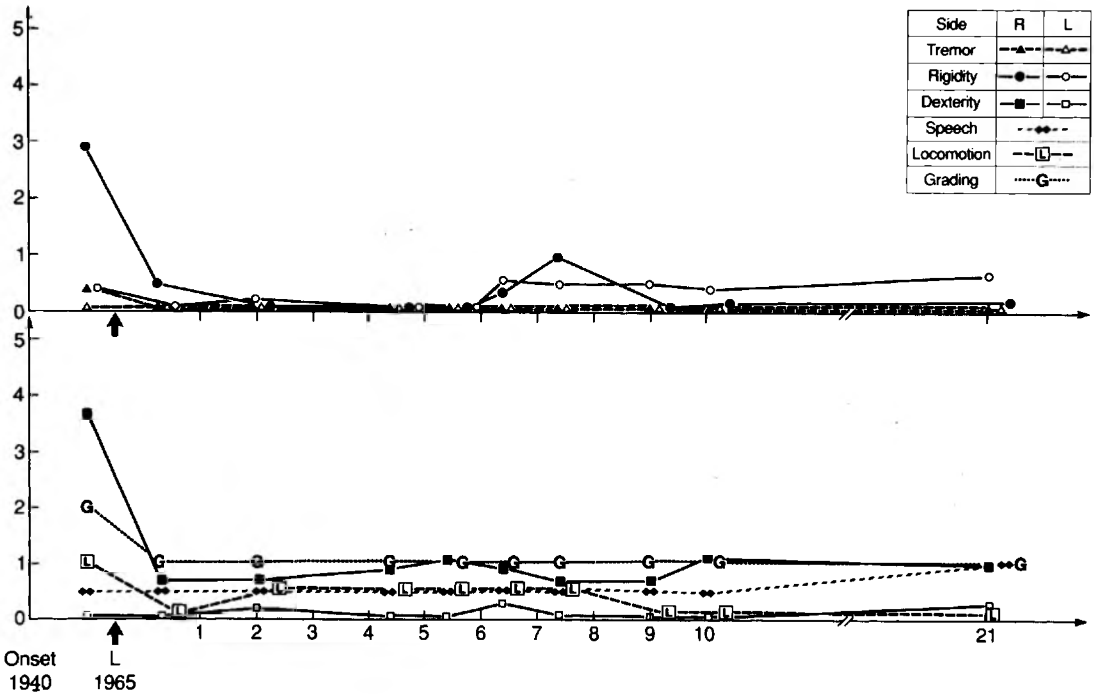

FIG. 7. Patient L: postencephalitic disease, onset age 28, unilaterally "successful" surgery, stable over 21 years. For explanation, see legend to Fig. 1.

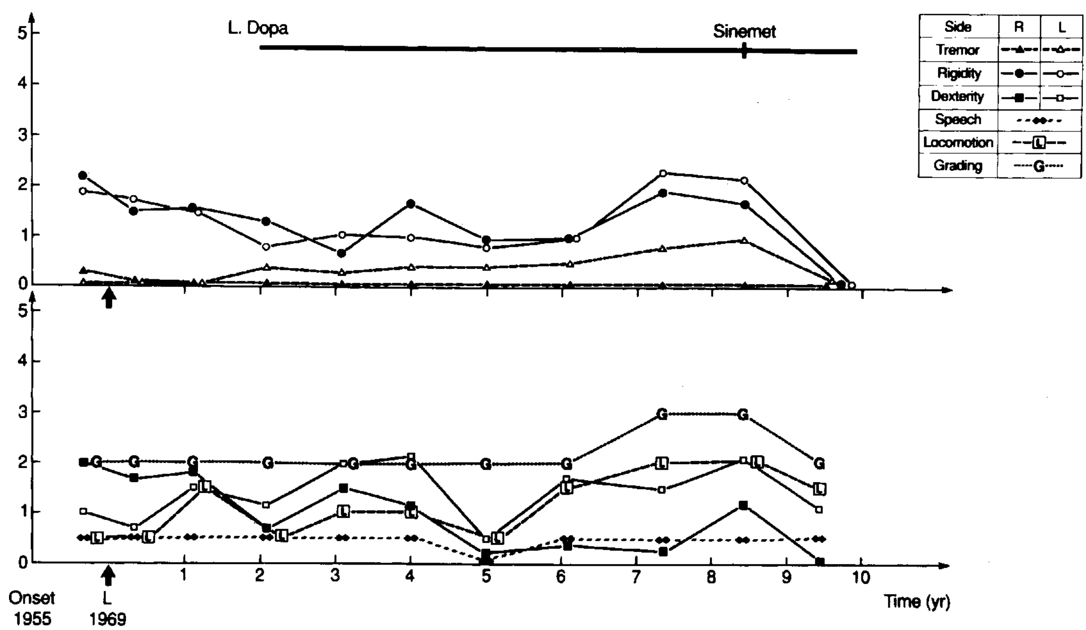

FIG. 8. Patient K: familial idiopathic disease, unilaterally "successful" surgery, stable over 10 years. For explanation, see legend to Fig. 1.

and left-sided tremor, rigidity, and dexterity and for locomotion and speech of no more than 0.2 points per year.

4. Deterioration in any one of the above categories of no more than 0.5 points in any one year or 1.0 point over entire follow-up.

Although the Matsumoto modification (10) of the Hoehn–Yahr (4) grading is somewhat insensitive to small changes in performance, we included this method of grading in order to compare our data with those of Matsumoto et al. (10) and others while the inclusion of our own 0 to 5 grading, described above (item 3), increases the sensitivity of the assessments. Although other methods of grading are now available, it was impossible to rework our data to use them. This was a retrospective study, and conditions of assessment could not be changed.

Though 5 years is perhaps a short time in which to judge stability, all but three patients who were judged stable on the basis of these criteria were followed 8 years or more.

Criteria for Successful Thalamotomy

A successful thalamotomy was defined as one that resulted in no tremor contralateral to the lesion and a mean score for contralateral rigidity of no more than 1.5 points; thus, a successful bilateral thalamotomy would result in no tremor on either side of the body and a mean rigidity score for the two sides of the body of no more than 3.0. In our experience (9,22,23) and that of others (26), though not all (5), tremor relieved for 3 months after a thalamotomy virtually never recurs.

Though some publications describe total abolition of rigidity after thalamotomy, the criteria on which such statements are based are unclear. In our experience, it is unusual to find a 0 rating of rigidity in each direction of movement of every limb joint while the patient pats rapidly with the opposite hand. Possibly this is because our thalamotomies were fashioned to relieve tremor, not rigidity, the latter not being considered a sufficiently significant disability to warrant the risks of the necessary enlargement of the lesion rostrally.

RESULTS

Patient Sample

Bilateral Thalamotomy

Seventy-one percent of the 55 bilaterally operated patients were male, and 66% had their first operation on the left. Average age of onset for their Parkinson's disease was 44.2 years, with an average of 6.2 years between onset and first thalamotomy and 3.0 years between sides. Six men and two women gave a history of encephalitis, and all but one of these eight experienced disease onset before age 40; 14 patients, 12 of them male, including the seven postencephalitics, experienced disease onset before 40. Five men and two women, one with disease onset before 40, gave a family history of parkinsonism. Thus, 14 of the 55 patients had disease of the PEY type, and 41 idiopathic Parkinson's disease.

The 55 bilaterally operated patients were younger on average when their disease began than 93 patients operated upon on only one side within a few weeks of the first operation in one of the patients undergoing bilateral surgery; this latter 93, in turn, averaged younger than 77 additional patients not accepted for surgery but seen at the same time as the operated cases. All groups averaged older after 1980 (see Table 2).

Unilateral Thalamotomy

Ten of the 15 PEY-type patients operated on unilaterally (see Patient Selection) were followed 5 years or longer and were further studied. Eight of the 15 gave a history of encephalitis, eight of disease onset before 40, and six of both. All selected 16 idiopathic cases operated on unilaterally were followed more than 5 years.

Follow-up

As shown in Table 3, 9 of 21 patients who were dead at the time of review in 1988 and 12 of 34 living at that time had been followed less than 5 years after their last surgery on the second side; five of the former and seven of the latter

TABLE 2. *Average age of onset of Parkinson's disease*

First seen or operated	Thalamotomy None	Unilateral	Bilateral
1960–1979	55.5 (n = 50)	49.4 (n = 57)	44.2 (n=55)
1980–1988	58.5 (n = 27)	55.1 (n = 36)	All but 3 before 1980

were rejected from the study for want of adequate follow-up, and four of the former and five of the latter were retained despite a short follow-up because it was already clear that their disease was progressing, leaving 43 patients for more detailed review.

Results of First Versus Second Side Thalamotomy

Because of unsatisfactory results, 6/43 first-sided (four on the left) and 14/43 second-sided (seven on the left) thalamotomies were repeated, two sides twice, and one thrice; 20 patients underwent repeated thalamotomies on the same side so that 2.5 procedures were done per patient. By our criteria (above), 48.8% of first-side thalamotomies were successful on the first try, 55.8% after 6 had been repeated. On the other hand, 37.2% of second-sided procedures were successful on the first try, 58.1% after 14 had been repeated. Thus, there seemed little difference in the eventual success of surgery on the first as compared to the second side, though initial success was less on the second side.

TABLE 3. *Follow-up after thalamotomy on the second side*[a]

21 Dead in 1988	34 Living in 1988
5 years or more	
n = 11	n = 23
5,5,6,8,9,10,11,12 12,24,24,	5,5½,7,7,8,8,8,8,8,8, 9,10,12,13,14,14,16, 18,18,19,20,23,24
Less than 5 years[a]	
n = 9	n = 12
0*,¾*,1¼*, 1½*,1½ 2*,2,2½,2½	¼*,¼*,¼*, ½*,2*,2½*, 2½*,2½,3,4,4,4½

[a]Cases with asterisk (*) rejected from study.

Interaction of Surgery with L-DOPA Therapy

Effect of L-DOPA Therapy

At the time of surgery on the first side, 7/43 patients were receiving L-DOPA therapy, whereas 11/43 were receiving this treatment at the time of the operation on the second side. Whereas 47.2% of pre-L-DOPA patients experienced successful surgery on the first side on the first try, and 55.6% after repetition, 57.1% of patients receiving L-DOPA experienced successful surgery, with no operations being repeated. On the other hand, 40.6% of pre-L-DOPA patients experienced successful surgery on the second side on the first try, and 50.0% after repetition, but 27.3% of post-L-DOPA patients experienced successful surgery on the second side on the first try, and 81.8% after repetition. Differences between patients operated on while receiving L-DOPA and those not are statistically significant (Mantel–Haenszel χ^2 = 0.68, p = 0.41).

Effect of Thalamotomy on DOPA Dyskinesia

Fifty-eight patient sides were at risk to develop DOPA dyskinesia in that L-DOPA therapy was instituted during follow-up of these 58 out of a total of 86 patient sides. Only 14 did so, four of whom had undergone previous successful, five unsuccessful, and five no contralateral thalamotomy; 44/58 patient sides at risk did not develop DOPA dyskinesia, 26 after previous contralateral successful, 15 unsuccessful, and three no thalamotomy. Five of 14 patient sides with DOPA dyskinesia were relieved by subsequent contralateral thalamotomy, four successful and one unsuccessful, leaving nine patient sides that continued to have dyskinesia after contralateral thalamotomy (two on the two sides of the

TABLE 4. *Dopa dyskinesia after thalamotomy: Patient sides at risk*

	Dyskinesia present	Dyskinesia absent	Incidence (%)
Previous thalamotomy	9	41	18
No thalamotomy	5	3	63
"Successful" thalamotomy	4	26	13
"Unsuccessful" thalamotomy	5	15	25

face of a single patient), two after successful and seven after unsuccessful contralateral thalamotomy.

The differences in incidence of DOPA dyskinesia following successful and unsuccessful or no thalamotomy were not statistically significant ($p = 0.08$, χ^2 test) but numbers are small (see Table 4).

Complications

Complications are listed in Table 5, and worsening of dysarthria in 16 (29%) patients, persistently in 15 (27%), was the most significant. In some patients it was difficult to decide if this deterioration in speech resulted from the surgery or the progress of disease. Dysarthria worsened after surgery on the first side in four patients (all on the left), the second side in 13 (eight on the right, five on the left), and both sides in one patient. Dysarthria worsened to a severe level after surgery on the second side in six of the 15 patients in whom it was persistent. Patients with worsening dysarthria averaged no older at the time of disease onset (40.8 years) than the group of 55 patients as a whole (44.2 years). The 13 patients whose speech worsened after operation on the second side averaged 49.1 years of age at the time of that surgery on the second side compared with 53.4 years for the whole group, and the interval between surgery on the two sides averaged 3.0 years in these patients, identical to that for the 55 patients as a whole. The four who worsened after surgery on the first side are too few to evaluate. Status of speech prior to surgery on the first or second side seemed to be related to this complication; surprisingly, the better the speech before either the first- or the second-side procedure, the more likely was postoperative deterioration. Thus, 80% of the deteriorating group had speech graded 0 to 1 before their first-side thalamotomy, 72% before the second, but in the nondeteriorating group 52% had speech graded this well before the first, 41% before the second. Numbers are too small to assess deterioration after first-side surgery.

TABLE 5. *Complications in 55 bilateral thalamotomies*

Persistent	
Worsening dysarthria	15
Mild dysphasia	2
Mild cognitive disorder	1
Cerebral infarct — slight hemiparesis and central pain	1
Foot dystonia	1
Transient	
Paresthesias	7
Dysphasia	3
Dysarthria	1
Oculomotor palsy	1
Hemiballismus (all postencephalitic patients)	4
Superficial infection	2

Dysphasia affected five patients, transiently in three, always after left-sided surgery. The two incidents of persistent dysphasia followed second-side surgery. Hemiballismus, as usual transient, occurred in four of the patients undergoing bilateral thalamotomy, all with PEY-type disease, in which condition it is a characteristic complication. (20)

Stability After Bilateral Thalamotomy

Data for the 13 patients who followed a stable course after bilateral thalamotomy from our 43

TABLE 6. *Clinical details: bilateral thalamotomy in stable patients*

Patient	Sex	? Familial	? Post-encephalitic	Age at onset of PD[e]	Follow-up years after first thalamotomy	Category points lost per year	Number of categories declining	M–H–Y grade[f] loss per year	Cause of death	Years onset of PD to first thalamotomy[e]	Years between sides
3	M	No	Yes	35	18	−0.6[b]	1[a]	−0.1[b]		5	10
14	M	No	Yes	18	24	?[c]	0?	0	"Epileptic fit" age 60	18	1
34	M	No	?	30	5	0.2	0	0		17	3
36	M	No	Yes	14	9	0.06	1[a]	0	Myocardial infarction	21	1
38	F	No	Yes	20	14	0	0	0		3	4.5
53	F	No	Yes	16	20	−0.06[b]	1[a]	0		29	5
9	M	No	No	43	11	0	0	0	Myocardial infarction	2	1
11	M	No	No	55	8	0.13	1[a]	0		10	1
25	M	No	No	52	14	?[c]	0	0		2	1
27	M	No	No	53	5	−0.7[b]	1[a]	−0.2[b]	Leukemia age 75	3	6
28	M	No	No	44	5	0	0	0	? "Not PD"	6	4
39	F	No	No	48	16	0.09	1	0		2	1.5
44	F	No	No	43	13	0	0	0		7	2

[a]Speech the declining category.
[b]Negative scores indicate improvement.
[c]Data in one category missing.
[d]US, unilateral "successful"; BS, bilaterally "successful"; BU, bilaterally "unsuccessful."
[e]PD, Parkinson's disease.
[f]M–H–Y, Matsumoto–Hoehn–Yahr.

with adequate follow-up are summarized in Table 6, data for the 30 who were unstable are in Table 7, using criteria defined above. Seven of the 13 stable patients showed no change in 0 to 5 scoring of all modalities or in grade over 5, 5, 11, 13, 14, 18, and 20 years, respectively, but four did not change grade but lost 0.06 to 0.2 points (mean 0.12) per year over 5, 8, 9, and 16 (mean 9.5) years. Six of the 13 stable patients lost over 0.5 but less than 1.0 point in a single category over 5 to 20 (mean 12.7) years of follow-up, five of the six in the speech category, which, as we have seen, could be a complication of bilateral surgery. Nine of the 30 unstable patients showed no deterioration in Matsumoto–Hoehn–Yahr grade over their entire postsurgical follow-up of 2½ to 18 (mean 6.9) years but did not meet criteria for stability in their 0 to 5 scoring of individual modalities. The whole group of unstable patients lost 0.1 to 5.1 (mean 1.2) points per year over 1.5 to 24 (mean 9.1) years.

Stability and PEY-Type Disease

We searched for factors that might influence stability. Six of 13 stable and 7 of 30 unstable patients had a history of either encephalitis ($n = 7$), disease onset before 40 ($n = 12$), or both ($n = 6$). Five of seven postencephalitic (71%), 6 of 12 youthful (50%), and 6 of 13 (46%) with either youthful onset, postencephalitic disease, or both became stable while only 7 of 30 (23%) idiopathic cases did so. This difference in achieving stability between idiopathic and PEY cases was significant ($\chi^2 = 7.1$, $p = 0.07$).

We compared age of onset of disease for the idiopathic stable and unstable groups in case the stable idiopathic cases might merely represent a subset of "hidden" PEY cases with disease onset only slightly over 40. Not only was the age of onset the same for the stable idiopathic patients (48.3 years) as for the unstable (48.4 years), but also there was no significant

Years onset to last thalamotomy	Right tremor score	Right rigidity score	Right tremor and rigidity score	Left tremor score	Left rigidity score	Left tremor and rigidity score	Left and right tremor score	Left and right tremor and rigidity score	"Success" score[d]
15	0.5	1	1.5	0	0.5	0.5	0.5	2	US
19	0	0	0	0	0	0	0	0	BS
20	0	1.5	1.5	0.2	1.0	1.2	0.2	2.7	US
22	0	1.5	1.5	0	1.5	1.5	0	3.0	BS
7.5	0	0.5	0.5	0	0	0	0	0.5	BS
34	0	0.5	0.5	0	0.5	0.5	0	1.	BS
3	0	2.5	2.5	0.1	1.3	1.4	0.1	3.9	US
11	0	0.7	0.7	0	0.5	0.5	0	1.2	BS
3	0	0	0	0	0	0	0	0	BS
9	0.7	2.5	3.2	0.1	0.5	0.6	0.8	3.8	BU
10	0	2.5	2.5	0	0.5	0.5	0	3	BS
3.5	0	1.5	1.5	0	1	1	0	2.5	BS
9	0	0.7	0.7	0	1	1	0	1.7	BS

difference in the incidence of stability in patients whose disease began between ages 40 to 45 (23%), 45 to 50 (17%), and over 50 (27%).

Stability after Unilateral Thalamotomy

Because stability after bilateral surgery appeared related to the diagnosis of PEY-type disease, we reviewed the data for our ten PEY and 16 idiopathic patients operated on unilaterally as listed in Table 8. Four of the ten (40%) PEY patients remained stable after unilateral thalamotomy, almost the same percentage as after bilateral thalamotomy in this type of patient. On the other hand, only 1 of 16 (6%) idiopathic cases was stable after unilateral thalamotomy. The difference was highly statistically significant ($p \leq 0.001$, $\chi^2 = 18.2$), further underlining the importance of PEY disease in determining patient stability.

Table 9 summarizes mean annual changes in our 0 to 5 ratings for the various groups of patients and the number of years of follow-up. Because stability has been defined partly on the basis of these 0 to 5 ratings, it is not surprising that average annual loss in ratings is low for stable patients regardless of type. Deterioration is greater in the unstable patients but similar across the various groups.

The Effect of Surgery on Postoperative Stability

Analysis of our data thus far indicates only that stability is related to PEY type disease. If the thalamotomy itself has any role to play in establishing stability, then one might expect that its timing and effectiveness would influence the result.

Timing of Surgery

If surgery slowed disease progress, it might be expected that the sooner bilateral surgery was completed, the higher might be the incidence of postoperative stability. Table 10 lists the intervals between disease onset and completion of surgery on the first and second sides for the

TABLE 7. *Clinical details: bilateral thalamotomy in unstable patients*[a]

Patient	Sex	? Familial	? Post-enceph-alitic	Age at onset of PD	Follow-up years after first thala-motomy	Category points lost per year	Number of cate-gories declining	M-H-Y grade loss per year	Cause of death	Years from onset to first thala-motomy
2	M	No	No	37	24	0.1	1	0		6
8	M	No	No	38	4	0.6	1	0.25		6
13	M	Yes	No	36	12	>0.13[b]	?	0.08	PD	6
19	M	No	No	37	23	>3.5[b]	?	0.04		7
20	M	No	Yes	42	4.5	1.3	4	0		2
26	M	No	No	35	8	0.5	3	0		4
55	M	No	Yes	26	2.5	0.8	1	0	Age 55 unknown	19
1	M	No	No	46	12	0.7	5	0.08	Age 75 PD	9
4	M	No	No	45	10	1.0	4	0.5	Pneumonia age 66	9
5	M	Yes	No	51	24	0.5	6	0.08	?Age 81	5
6	M	No	No	41	19	1.1	6	0.1		5
7	M	Yes	No	52	6	1.0	3	0.17	?Age 71	4
10	M	No	No	45	2.5	2.7	4	0.8		3
12	M	No	No	44	2.5	2	3	0		4
17	M	No	No	56	2.5	2.6	4	0	?Age 65	2
18	M	Yes	No	55	10	0.2	1	0.1		3
21	M	No	No	42	8	>0.3[b]	>1	?		7
24	M	No	No	44	12	1.1	6	0		8
29	M	No	No	48	7	1.2	4	0.2		8
30	M	No	No	45	18	0.3	4	0		3
32	M	No	No	50	2	2.1	3	0.5	?Age 74	3
35	M	No	No	47	7	?	?	0.14		1
40	F	No	No	46	8	0.9	4	0		10
41	F	No	No	45	8	0.3	1	1.3		9
42	F	No	No	51	7.5	0.7	3	0.2		4
43	F	No	No	45	4	2.6	5	0		1
48	F	Yes	No	64	1.5	5.1	4	1.7	?Age 68	2
50	F	No	No	55	5.5	0.6	3	0.4		3
51	F	No	No	41	8	0.7	4	0.1	Heart failure age 68	8
52	F	No	No	55	9	1	6	0.06		4

[a]Abbreviations as in Table 6.
[b]Data in one category missing.

various groups of patients. The intervals are longest, not shortest, in the stable PEY, shorter in the unstable PEY, and shorter still in the idiopathic groups. Though the intervals are slightly longer, with a mean of 8.1 years to completion of surgery in the unstable compared with 6.9 years in the stable idiopathic groups, these differences are not statistically significant ($p = 0.49$).

The differing incidences of stability in idiopathic patients with surgery completed within 5 years of disease onset (38%), 5–10 years (20%) and over 10 years (14%) were also not statistically significant. Thus there is no apparent effect of surgical time frame on the incidence of stability.

Effect of Surgery Outcome on Postoperative Stability

If surgery influenced the course of Parkinson's disease, there might be some correlation between the overall total reduction or the finally achieved residual level of tremor and rigidity and incidence of stability.

Operatively Induced Total Reduction in Tremor and Rigidity

From Tables 6 to 8, degrees of reduction in the 0 to 5 scores for tremor and rigidity were compared with the incidence of postoperative

Years between sides	Years onset to last thalamotomy	Right tremor score	Right rigidity score	Right tremor and rigidity score	Left tremor score	Left rigidity score	Left tremor and rigidity score	Left and right tremor score	Left and right tremor and rigidity score	"Success" score
3	9	0.1	1.7	1.8	0.2	1.5	1.7	0.3	3.5	BU
2	8	2	2	4	0.5	1.2	1.7	2.5	5.7	BU
3	9	0.3	3	3.3	1.5	2	3.5	1.8	6.8	BU
6	13	0.5	1	1.5	0	1	1	0.5	2.5	US
7	9	0	2.5	2.5	0.1	1.3	1.4	0.1	3.9	US
4.5	8.5	0	0	0	0.2	1.2	1.4	0.2	1.4	US
2	21	0	1.5	1.5	0	0.3	0.3	0	1.8	BS
3	12	1.5	2	3.5	0.5	1	1.5	2	5	BU
1	10	0	1.5	1.5	0.2	2	2.2	0.2	3.7	US
0.5	5.5	0.7	3	3.7	0	2	2	0.7	5.7	BU
2	7	1	0.5	1.5	0.5	2	2.5	1.5	4.0	BU
3.5	7.5	0.2	1.5	1.7	0.2	1.5	1.7	0.4	3.4	BU
2.5	5.5	0	1.2	1.2	0.5	2	2.5	0.5	3.7	US
1	5	0	1.7	1.7	0	1	1	0	2.7	US
0.5	2.5	2	1.6	3.6	1	2	3	3	6.6	BU
1	4	0	1	1	0.2	2	2.2	0.2	3.2	US
1	8	0	0	0	0	0	0	0	0	BS
0.5	8.5	0.1	2.5	2.6	1.5	2.5	4	1.6	6.6	BU
5	13	1	1.7	2.7	1.7	1.7	3.4	2.7	6.1	BU
3.5	6.5	0	1.3	1.3	0.7	1.5	2.2	0.7	3.5	US
4	7	0	1.5	1.5	1	3	4	1	5.5	US
12	13	0	0	0	0	0	0	0	0	BS
5	15	0.5	1.2	1.7	1	2	3	1.5	4.7	BU
0.5	9.5	0.2	1.5	1.7	1	1.5	2.5	1.2	4.2	BU
2	6	0.5	1	1.5	2.7	2.5	5.2	3.2	6.7	BU
1	2	0	1.7	1.7	0	1.7	1.7	0	3.4	BU
1	3	1	1.3	2.3	0.2	1	1.2	1.2	3.5	BU
8.5	11.5	0.1	0	0.1	0	0	0	0.1	0.1	US
9.5	17.5	0	0.5	0.5	0.1	0.5	0.6	0.1	1.1	US
3.5	7.5	0.1	1.5	1.6	1	3	4	1.1	5.6	BU

stability for bilateral and unilateral thalamotomy in PEY and idiopathic groups. No significant differences were found for overall postsurgical total reduction of tremor or rigidity or both on the right or the left sides between the stable and unstable groups except for a slightly significant ($p = 0.027$) reduction of left-sided rigidity in the stable group.

Final Residual Tremor and Rigidity Scores (Success) after Thalamotomy

The relationship between residual tremor and rigidity when surgical treatment was complete—the success of the surgery—and the incidence of stability was examined. Criteria for success have been presented. Thus, a patient undergoing bilateral thalamotomy might have bilaterally or unilaterally successful or bilaterally unsuccessful surgery, and one undergoing unilateral thalamotomy might have a (contralaterally) unilaterally successful or unsuccessful operation.

For unilateral cases, we also rated residual tremor and rigidity ipsilateral to the thalamotomy and examined degree of success in the light of residual tremor and rigidity on both sides, using the same criteria even though an operation had been performed only on one side, as shown in Table 8.

TABLE 8. *Clinical details: unilateral thalamotomy*[a]

Patient	Sex	? Familial	? Postencephalitic	Age at onset of PD	Follow-up years after thalamotomy	Side of thalamotomy	Category points lost per year	Number of categories declining	M-H-Y grade lost per year	Cause of death	Years from onset to thalamotomy
E	M	No	Yes	43	10	L	0.15	1	0		13
R	M	No	Yes	20	10	L	0	0	0		30
G	M	No	Yes	21	9.5	L	0.02	0	0		11
L	F	No	Yes	28	21	L	0.08	0	0		25
K	M	Yes	No	43	10	L	0	1	0		3
B	F	No	Yes	37	6.5	R	0.9	4	0.15		9
C	M	No	Yes	27	16	L	0.5	4	0.11		29
S	M	No	Yes	37	21	R	0.5	5	1		10
M	F	No	Yes	43	7	L	>0.4[b]	?	0.07		9
H	F	No	Yes	37	5	R	1.1	3	0.2		5
R	M	No	No	39	11	L	0.5	3	0.18		10
B	M	No	?No	56	6.5	R	1.9	5	0.15		1
A	M	No	?No	61	4	L	?[b]	?	0.5		5
T	M	No	No	47	12	R	0.6	3	0.08		4
A	M	No	No	51	9	L	0.9	4	0.11		2
O	M	No	No	50	7	L	0.9	3	0.14		3
Bor	F	No	No	48	11	L	1.3	5	0.09		2
Bor	M	No	No	40	19	L	0.2	3	0.05		5
W	F	No	No	52	9	L	0.4	2	0.1		1
Ri	F	No	No	53	11	R	1	6	0.09		6
F	M	No	No	44	8	L	1.5	5	0.25		2
C	M	No	No	50	5	R	1	3	0.3		7
H	M	No	No	63	7	L	1.2	5	0.2		5
Q	F	Yes	No	56	11	R	0.2	2	0.09		15
B	F	No	No	55	13	L	0.5	3	0.08		10
W	F	No	No	51	12	L	1	5	0.17		4

[a]Abbreviations as in Table 6.
[b]Data in one category missing.
[c]UU, unilaterally unsuccessful.

In our patients operated on bilaterally, tremor that was completely abolished contralaterally for 3 months never recurred during follow-up in 63/66 patient sides, and rigidity in 12/19 patient sides.

Table 11 summarizes the results for the various groups.

Stable patients exhibited similar residual levels of tremor and rigidity after all surgery had been completed regardless of disease types, as

TABLE 9. *Thalamotomy and changes in semiquantitative performance scores in Parkinson's disease*

	Postencephalitic–youthful thalamotomy		"Idiopathic" thalamotomy	
	Unilateral (n = 10)	Bilateral (n = 13)	Unilateral (n = 16)	Bilateral (n = 30)
Stable (%)	40	46	6	23
Points lost/yr	0.02–0.1 (mean 0.06)	0–0.2 (mean 0.05)	0	0–0.13 (mean 0.04)
Follow-up (yrs)	9.5–21 (mean 13)	5–24 (mean 15)	10	5–16 (mean 10.3)
Unstable (%)	60	54	94	77
Points lost/yr	0.5–1.1 (mean > 0.7)	0.5–3.5 (mean > 1.0)	0.2–1.9 (mean 0.9)	0.2–5.1 (mean 1.3)
Follow-up (yrs)	5–21 (mean 11.1)	2.5–23 (mean 9.0)	4–19 (mean 9.6)	1½–24 (mean 8.4)

	Contra-lateral tremor score	Contra-lateral rigidity score	Contra-lateral tremor and rigidity score	Ipsilateral tremor score	Ipsi-lateral rigidity score	Ipsilateral tremor and rigidity score	Left and right tremor score	Left and right tremor and rigidity score	"Success" score	Success score if calculated as if operated bilaterally
	0	0.5	0.5	0.1	1.2	1.3	0.1	1.8	US	(US)
	0	0.5	0.5	0	0.1	0.1	0	0.6	US	(BS)
	0	1	1	0	0.1	0.1	0	1.1	US	(BS)
	0	0.2	0.2	0	0.2	0.2	0	0.4	US	(BS)
	0	1.5	1.5	0.5	1.5	2	0.5	3.5	US	(US)
	0.1	1.1	1.2	0.5	2.5	3.0	0.6	4.2	UU[c]	(BU)
	0.3	3.5	3.8	0.5	3	3.5	0.8	7.3	UU	(BU)
	0.1	2	2.1	0.5	2	2.5	0.6	4.6	UU	(BU)
U	N	A	V	A I	L	A	B	L	E	?
	0	0.7	0.7	0.5	3.2	3.7	0.5	4.4	US	(US)
	0	0.2	0.2	0.7	1.5	2.2	0.7	2.4	US	(US)
	0.1	3	3.1	0	3	3	0.1	6.1	UU	(BU)
	0.5	?	?	0.5	?	?	1.0	?	US	(BU)
	0	1	1	0.5	2	2.5	0.5	3.5	US	(US)
	0	1	1	0.5	0.7	1.2	0.5	2.2	US	(US)
	0	2	2	0	2	2	0	4	UU	(BU)
	0	1.2	1.2	0.5	2.5	3	0.5	4.2	US	(US)
	0	1.5	1.5	0	2.5	2.5	0	4	US	(US)
	0.1	0.5	0.6	0.5	0.7	1.2	0.6	1.8	UU	(BU)
	0.5	1.5	2	1.2	1.5	2.7	1.7	4.7	UU	(BU)
	0.1	2	2.1	0.5	2	2.5	0.6	4.6	UU	(BU)
	0.2	4	4.2	0.5	4	4.5	0.7	8.7	UU	(BU)
	0.5	2	2.5	0.7	2.5	3.2	1.2	5.7	UU	(BU)
	0	0.7	0.7	0.7	1.2	1.9	0.7	2.6	US	(US)
	0	1.5	1.5	0.7	3.5	4.2	0.7	5.7	US	(US)
	0	1	1	0.2	1.5	1.7	0.2	2.7	US	(US)

did unstable ones, but there were considerable differences between these scores in the stable and unstable patients. Even after unsuccessful surgery, tremor was minimal except in three of the total of 86 patient sides studied, and rigidity was minimal in all but 27 of the 86 patient sides.

When residual tremor and rigidity levels were computed for both sides of the body after unilateral thalamotomy, as described above, residual tremor and rigidity scores were similar in stable and unstable patients to those achieved after bilateral surgery for stable and unstable patients,

TABLE 10. *Timing of thalamotomy and progress of Parkinson's disease (years)*

Group	Disease onset to first side thalamotomy	First to second side thalamotomy	Onset to completion of surgery
Postencephalitic–Youthful			
Stable			
Bilateral thalamotomy	15.5	4.1	19.6
Unilateral thalamotomy	19.8	—	19.8
Unstable			
Bilateral thalamotomy	7.1	3.5	11.0
Unilateral thalamotomy	12.0	—	12.0
Idiopathic			
Stable			
Bilateral thalamotomy	4.6	2.4	6.9
Unilateral thalamotomy	3.0	—	3.0
Unstable			
Bilateral thalamotomy	5.0	3.1	8.1
Unilateral thalamotomy	4.8	—	4.8

TABLE 11. *Residual contralateral tremor and rigidity after thalamotomy*

Group	Total residual tremor (mean)		Total tremor and rigidity (mean)	
	Contralateral to thalamotomy	Bilateral[a]	Contralateral to thalamotomy	Bilateral[a]
Postencephalitic–youthful				
Stable				
Unilateral thalamotomy	0 [0]	0–0.5 [0.2]	0.2–1.0 [0.6]	0.4–1.8 [10]
Bilateral thalamotomy	0–1.2 [0.6]		0–3.0 [1.5]	
Unstable				
Unilateral thalamotomy	0–0.3 [0.1]	0.5–0.8 [0.6]	0.2–3.8 [1.6]	2.7–7.3 [4.5]
Bilateral thalamotomy	0–2.5 [0.8]		1.4–6.8 [3.6]	
Idiopathic				
Stable				
Unilateral thalamotomy	0 (1 case only)	—	1.5 (1 case)	—
Bilateral thalamotomy	0–0.8 [0.13]		0–3.9 [2.3]	
Unstable				
Unilateral thalamotomy	0–0.5 [0.13]	0–1.7 [0.7]	0.6–4.2 [2.2]	1.8–8.7 [4.2]
Bilateral thalamotomy	0–3.2 [1.0]		0–6.6 [3.9]	

[a]Bilateral scores in patients operated unilaterally.

respectively, even though these levels were achieved by surgery on only the one (contralateral) side.

Thus, there appeared to be a correlation between low residual levels of tremor and rigidity, however achieved, and stability.

We now correlated disease type, postoperative stability, whether surgery was unilateral or bilateral, and success of surgery, as shown in Table 12.

The relationship between success and stability was not statistically significant for the bilaterally operated PEY patients, but it was ($p < 0.001$ with the χ^2 test) for the unilaterally operated. For bilaterally operated idiopathic cases, the relationship between surgical success and stability was also statistically significant at the $p < 0.0027$ level with the χ^2 test but not for unilateral thalamotomies.

We also correlated stability and residual tremor and rigidity for unilaterally operated cases but calculated the residual tremor and rigidity bilaterally, as if the patients had been operated on bilaterally as described above (see Table 13).

These correlations also suggest a relationship ($p = 0.0006$, $\chi^2 = 14.8$) between postoperative stability and degree of residual tremor and rigidity, whether or not related to the actual surgery.

TABLE 12. *Success of thalamotomy versus postoperative stability*

Disease type	Thalamotomy	Success	Percentage stable after this surgery[a]	Percentage of all stable cases in this category	Percentage of all unstable cases in this category
PEY	Unilateral	Contralateral	(4/6) 67*	(4/4) 100	(2/5) 40
		Fail	(0/3) 0	(0/4) 0	(3/5) 60
	Bilateral	Bilateral	(4/5) 80 n.s.	(4/6) 67	(1/7) 14
		Unilateral	(2/5) 40	(2/6) 33	(3/7) 43
		Fail	(0/3) 0	(0/6) 0	(3/7) 43
Idiopathic	Unilateral	Contralateral	(1/8) 11 n.s.	(1/1) 100	(8/15) 3
		Fail	(0/8) 0	(0/1) 0	(7/15) 47
	Bilateral	Bilateral	(5/7) 71*	(5/7) 71	(2/23) 9
		Unilateral	(1/9) 11	(1/7) 14	(8/23) 35
		Fail	(1/14) 7	(1/7) 14	(13/23) 57

[a]n.s., not statistically significant; *statistically significant.

TABLE 13. *Stability after unilateral thalamotomy related to bilateral residual tremor and rigidity (PEY and idiopathic cases)*

"Success"[a]	Percentage stable after this category of surgery	Percentage of all stable (unilateral) cases in this category	Percentage of all unstable unilateral cases in this category
Bilateral	(3/3) 100	(3/5) 60	(0/20) 0
Unilateral	(2/11) 18	(2/5) 40	(9/20) 45
Fail	(0/11) 0	(0/5) 0	(11/20) 55

[a]Calculated as for bilateral thalamotomy.

Familial Parkinson's Disease

Six of our 43 bilaterally operated patients had a family history of Parkinson's disease, one with disease onset at age 36. Only the latter patient achieved postoperative stability, and only he and one other enjoyed "successful" surgery. Numbers are too small to assess.

DISCUSSION

We have reviewed the long-term (up to 24 years) course of 43 patients with Parkinson's disease, 13 of the PEY and 30 the idiopathic (10) type, after bilateral thalamotomy, stimulated by the report by Matsumoto et al. (10) that thalamotomy might affect the course of Parkinson's disease. This is the largest report series of such patients of which we are aware, though Cooper (3) mentions 250 personal cases. Criteria have been suggested for defining stability of postoperative course and successful as compared with nonsuccessful thalamotomy.

The mean time frame of surgery in our patients is almost identical to that of Matsumoto et al. (10): 44.2 years at disease onset, a 6.2-year interval between onset and completion of thalamotomy on the first side, and 3.0 years between surgery on the two sides in our series, compared with 44.5, 4.0, and 3.0 years, respectively, in the Japanese series. The 43 patients operated on bilaterally were younger than those operated on unilaterally during the same years, and all operated patients were younger still than those seen in consultation but not selected for surgery over the same time period.

In keeping with the observations of others (3,26) that it is more difficult to relieve tremor and rigidity on the second side than on the first, six first-sided and 14 second-sided procedures had to be repeated to achieve a satisfactory result, though eventual success rates were similar for the two sides. Difficulty with the second side may be more apparent than real, for it is less likely that patients would undergo surgery on the second side unless the procedure on the first had been successful; thus, patients undergoing bilateral thalamotomy are selected for success on the first side but not the second.

In contradistinction to published opinions (3,10,26), concomitant L-DOPA therapy had no statistically significant effect on surgical success, but, as noted by ourselves (19) and others (5,10,13,14), a prior thalamotomy reduced the incidence of DOPA dyskinesia in our series from 63% to 18%.

Of six familial cases, only two enjoyed "successful" surgery, and only one, a PEY case, became stable, but the numbers are too small to evaluate.

The major complication of bilateral thalamotomy as reported by others (3,26) was worsening of dysarthria, affecting 27% of our cases. Cooper (3) noted this complication in 50% of patients immediately after surgery on the second side, though the incidence fell to 18% by the time the patient left the hospital. It appeared after the second side surgery in 13 of our patients, the first in only four (all on the left), and after both in one. Our dysarthric patients were no older than patients not suffering from this complication, and the interval between sides was the same, but the better the speech before either the first-or the second-side procedure, the more likely it was to deteriorate postoperatively. Possibly the patients with the best speech are more likely to suffer from small changes than those more seriously affected. Gait disturbance, a common complication in Cooper's (3) bilateral series, was rare in ours. The predilection for our PEY-type patients to develop temporary postoperative hemiballismus was in keeping with the observations by others (20).

But our chief interest was in the effect, if any, that surgery might have on the progress of Parkinson's disease. Other than the report of Matsumoto et al. (10), there appears to be little published evidence to support the notion that thalamotomy alters the progress of Parkinson's disease. Kelly and Gillingham (5) followed 60 patients for 10 years after thalamotomy and found no evidence that the procedure did more than arrest tremor and rigidity. Nagaseki et al. (12) followed 27 patients undergoing thalamotomy for Parkinson's disease for up to 10 years without noticing evidence of alteration of disease progression. Narabayashi (13) comments on the maintenance of activities of daily living for even 10 to 20 years after thalamotomy but states: "Most of the highly successful patients are bilaterally operated on, with satisfactory elimination of rigidity and tremor on both sides of the body. Also, most have either tremor-dominant disease with minimum primary akinesia or juvenile disease." Even though he found juvenile Parkinsonism slower in its progression, the long-term (10 to 20 years) course was downhill.

It is difficult to account for any slowing of progression that surgery might induce. Several factors must be considered, the first of which is the wide variation between patients in the natural progress of the disease. Matsumoto et al. (10) had noted considerable variation among reported series, as shown in his graph. Tetrud and Langston (25), in their trial of the efficacy of deprenyl, reported deterioration in the Hoehn–Yahr scale of 0.73 ± 0.15 per year in patients receiving placebo and 0.263 ± 0.10 per year for those on deprenyl. We have recalculated the deterioration in Hoehn–Yahr grade in the 22 bilaterally operated patients of Matsumoto et al. (10) at 0.16 per year, in his patients with disease onset before age 40 at 0.13 per year, his cases listed as showing no progression at 0.11 per year (see Table 14). Our stable patients, by definition, showed 0 grade change, while our idiopathic unstable patients deteriorated at 0.17 per year, unstable PEY cases at 0.05 per year, and all unstable patients at 0.14 per year. These variations must be kept in mind in assessing the effect of any particular treatment modality, for they are greater than those seen between groups of operated patients.

Thirteen of our 43 patients (30.2%) followed what we defined as stable courses after bilateral thalamotomy, 46% of the patients with PEY, 23% idiopathic type disease, the difference being statistically significant. Forty percent of ten PEY patients but only 6% of 16 idiopathic cases ran stable courses after unilateral thalamotomy, the differences being highly statistically significant. Among idiopathic cases there were no significant differences between ages of onset of disease in stable and unstable cases, lending no support to the notion that the stable idiopathics might represent "hidden" PEY cases with disease onset a little over age 40.

These observations support the generally held opinion (10,13,16) that PEY-type disease is more benign than idiopathic, with progression so slow as to pass undetected, so that any apparent stability after surgery in these patients is the result of the inherent nature of the disease and

TABLE 14. *Variation in the progression of Parkinson's disease*

	Loss of Matsumoto–Hoehn–Yahr grade/year
Tetrud et al.	
Patients receiving placebo	0.73 ± 0.15
Patients receiving deprenyl	0.263 ± 0.10
Matsumoto et al.	
All 20 bilateral cases	0.16
All juvenile cases	0.13
All "no progression" cases	0.11
Tasker et al.	
Idiopathic unstable	0.17
All unstable	0.14
Unstable postencephalitic juvenile	0.05
All stable	0.0

not of the surgery itself. Matsumoto et al. (10) noted slower progression in patients who were relatively young when treated, with a preoperative history of parkinsonism extending over 11 years, in whom tremor was the major symptom, and who were not being treated with L-DOPA. Thirty-one of their 64 patients failed to show progression of their Parkinson's disease after unilateral thalamotomy, but details are not given. They document 15 of 22 patients considered nonprogressive after bilateral thalamotomy. If we interpret their table correctly and reclassify their data according to our criteria for stability, then only five of their 22 patients (patients 1, 2, 3, 5, and possibly 6) were stable after second-side surgery by our criteria, because the others dropped in grade during follow-up. Four of these five stable patients experienced disease onset below the age of 40 and hence would fit into our PEY group, whereas in only two of the 17 unstable patients did disease begin before 40. Thus, their data are in keeping with ours with respect to the influence of PEY disease on parkinsonian stability after surgery. Scott et al. (16) found that a history suggesting encephalitis and absence of familial neurologic disease favored slow progress in parkinsonism. However, Narabayashi (13) states, "Even in slowly progressing JP (juvenile parkinsonism), however, long-term (10- 20-year) course is downhill." And "Although the course for certain bilaterally operated on juvenile parkinsonians appears stationary, in 10- 20-year follow-up slight deterioration . . . occurs." We have seen two patients with juvenile or postencephalitic strictly unilateral Parkinson's disease that was unquestionably arrested, one undergoing unilateral thalamotomy and the other unoperated.

But does the difference between idiopathic and PEY disease explain all the observations? If surgery influenced progression of disease, then early completion of bilateral thalamotomy might be expected to be associated with an enhanced incidence of stability. In fact, surgery was completed very late in PEY cases, especially in stable patients, whereas in idiopathic cases there was no real difference between surgical time frames for the stable and unstable groups. This again supports the concept that disease stability and not surgery is the major factor determining progress of the disease.

If surgery influences disease progression, it is logical to expect that effective surgery that is successful in relieving tremor and rigidity would be more likely to induce stability than unsuccessful surgery. Our data confirm the view (12,13,23, 26) that once surgery abolishes tremor, and to a lesser extent rigidity, these modalities do not recur after 3 months.

We first examined total reduction of tremor and rigidity achieved by surgery but found that this feature did not correlate with achievement of stability.

When we examined the degree of residual tremor and rigidity left after completion of surgery, there was a marked difference in levels between stable and unstable groups but little difference within the stable and unstable groups themselves. When success and stability were correlated, we found that the incidence of stability was greatest in both PEY and idiopathic patients with bilaterally successful thalamotomy as defined by us, less so after unilaterally successful surgery, and minimal after bilaterally "failed" surgery. These observations suggest that achievement of minimal tremor and rigidity by surgery may be associated with stability of disease progress in both the PEY and idiopathic patients. These observations tend to support the notion that successful surgery that does, in fact, abolish tremor and rigidity leads to stabilization of the disease, quite apart from any influence the PEY type might exert.

Curiously, when unilaterally operated patients were examined, overall residual tremor and rigidity scores on the two sides, even though only one side of the brain had been operated on, also appeared related to stability, as shown in Table 13. Thus, although postoperative stability is related to low residual tremor and rigidity scores after surgery, the data for unilateral cases suggest that it is the eventually achieved low levels of tremor and rigidity that are important, not as the result of surgery necessarily.

Thus, although the apparent stabilization of Parkinson's disease after surgery appears to be the result of its performance in patients with relatively stable PEY-type disease, there is evidence to suggest that low levels of residual tremor and rigidity in either PEY or idiopathic cases also correlate with stability, whether achieved by surgery in the bilateral cases or not, as in the case of unilaterally operated cases. It is difficult to explain this observation on the basis of the known pathophysiology (8,22) of thalamotomy for surgical interruption of any malevolent process that might influence the progress of Parkinson's disease. That progress is largely determined by the course of bradykinesia, on which thalamotomy is not known to exert a dramatic effect, though the older pre-L-DOPA literature suggests a small benefit (6,15,18,26).

Yet recent studies by Bergman et al. (2) and Aziz et al. (1) have shown that lesions made in corpus Luysii ameliorate bradykinesia in monkeys rendered unilaterally parkinsonian with MPTP. Laitinen et al. (7) have drawn attention to the early work of Leksell and his group (17), suggesting that pallidotomy reduces bradykinesia in parkinsonian patients, and gone on to present convincing evidence of their own to support that statement. Thus, it is not inconceivable that destructive lesions appropriately placed elsewhere, such as in the thalamus, might also affect bradykinesia and influence disease progression.

Perhaps the relative absence of tremor and rigidity, however achieved, helps the patient to be more effective in combating functional deterioration. Or perhaps some idiosyncratic feature is involved, so that patients in whom tremor and rigidity are more readily controlled, whether suffering from PEY or idiopathic disease, are more likely to progress slowly. Another possibility is that the stable non-PEY cases represent a special subgroup of idiopathic disease that behaves like the PEY type, though we were unable to identify any clinical features such as age of onset that distinguished them from the larger group of unstable idiopathic cases.

Thus, apparent lack of progress of Parkinson's disease after thalamotomy is most clearly related to the presence of PEY disease, but there is also a correlation that is difficult to explain with successful reduction of tremor and rigidity to low residual levels whether achieved entirely by surgery or not.

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