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Stereotactic Radiofrequency Pallidothalamic Tractotomy for Medically Refractory Parkinson's Disease: A Prospective Study of Clinical Outcomes and Safety

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Abstract

Background: Despite optimized pharmaceutical treatment, debilitating stiffness, bradykinesia, tremor, motor fluctuations and gradual functional impairment occur in medically resistant Parkinson's disease (PD). Deep brain stimulation (DBS) is an established surgical therapy, but its cost, implanted hardware, need for postoperative programming, and requirement for longterm specialized follow-up may limit access in various healthcare settings. A permanent, hardware-free approach is stereotactic radiofrequency lesioning. The pallidothalamic tract (PTT) is situated in Forel's field H1 and is a prominent efferent channel from the globus pallidus internus to the motor thalamus, and hence may be a useful target for ablative therapy.

Objective: To evaluate the clinical efficacy, durability, and safety of stereotactic radiofrequency pallidothalamic tractotomy in patients with medically refractory Parkinson's disease.

Methods: This prospective clinical study included 34 consecutive patients with medically refractory Parkinson's disease who underwent MRI/CT-guided stereotactic radiofrequency PTT at the Functional Neurosurgery Unit, Al-Sadr Teaching Hospital, Basra, Iraq. The PTT was targeted within Forel's field H1 using stereotactic MRI–CT fusion and individualized anatomical planning. Radiofrequency lesioning was performed using a temperature-controlled technique.

Clinical outcomes were assessed preoperatively and at one month and one year postoperatively using the UPDRS-III, contralateral rigidity, contralateral tremor, and Hoehn & Yahr stage. Postoperative complications and clinical recurrence were prospectively recorded.

Results: The mean UPDRS-III OFF score decreased from 42.4 ± 5.4 preoperatively to 20.2 ± 4.2 at one month and 18.1 ± 3.6 at one year, corresponding to improvements of 52.4% and 57.3%, respectively ($p < 0.001$). Contralateral rigidity decreased from 3.25 ± 0.64 to 1.20 ± 0.52 at one month and 0.75 ± 0.49 at one year, representing improvements of 63.1% and 76.9%, respectively ($p < 0.001$). Contralateral tremor decreased from 3.00 ± 0.73 to 0.82 ± 0.75 and 0.65 ± 0.65, corresponding to improvements of 72.7% and 78.3%, respectively ($p < 0.001$). The mean Hoehn & Yahr stage decreased from 2.83 ± 0.29 to 1.64 ± 0.22 at one month and 1.08 ± 0.18 at one year, corresponding to

improvements of 42.0% and 61.8%, respectively ($p < 0.001$). Postoperative complications included headache in 19 patients (55.9%), balance disturbance in 2 (5.9%), facial or arm weakness in 2 (5.9%), numbness/tingling in 1 (2.9%), and speech disturbance in 1 (2.9%). No intracerebral hemorrhage, stroke, or seizure was observed, and no clinical recurrence was recorded during follow-up.

Conclusion: Stereotactic radiofrequency pallidothalamic tractotomy was associated with substantial and sustained improvement in motor function and disease severity in patients with medically refractory Parkinson's disease. Notable improvements in UPDRS-III OFF, contralateral stiffness, contralateral tremor, and Hoehn & Yahr stage were observed at one month and were sustained or improved at one year. The procedure had a positive safety profile, with no intracerebral hemorrhage, stroke, seizure, or recurrence. PTT may therefore serve as a viable and long-lasting non-hardware ablative alternative for meticulously chosen individuals suffering from medically resistant Parkinson's disease. More extensive prospective research with consistent long-term monitoring is needed to confirm these results.

Keywords: Parkinson's Disease, Pallidothalamic Tractotom, Pallidothalamic Tract, Forel's Field H1, Radiofrequency Lesioning, Stereotactic Neurosurgery, Functional Neurosurgery, UPDRS, Ablative Surgery, Movement Disorders.

Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder marked by the impairment of basal ganglia thalamocortical motor pathways, resulting in resting tremors, rigidity, bradykinesia, gait abnormalities, and a gradual reduction in functional independence. Although dopaminergic therapy serves as the primary treatment method, many patients eventually suffer from incapacitating motor fluctuations, dyskinesia, medication-resistant tremors, rigidity, or significant "off" periods, despite optimum pharmacological management [1–5]. Functional neurosurgery has a recognised function for individuals with Parkinson's disease whose motor symptoms persistently hinder their quality of life, even with optimum pharmacological treatment. Deep brain stimulation (DBS), especially targeting the subthalamic 2 nucleus (STN) and the globus pallidus internus (GPi), has shown significant effectiveness in well-chosen individuals [6–9]. Nonetheless, DBS necessitates the enduring installation of hardware, postoperative configuration, battery substitution, and sustained access to specialist multidisciplinary healthcare. These stipulations may impose practical and financial constraints, especially in healthcare systems where sophisticated neuromodulation treatments are not easily accessible. The patient's age, existing health conditions, cognitive or mental health state, and personal treatment choices may also affect the appropriateness of DBS [6,7,15,16]. Stereotactic ablative techniques offer a surgical option that avoids the need for permanent hardware implantation and the associated device calibration. Advances in stereotactic MRI and CT imaging, together with modern radiofrequency technology, have enabled greater precision in targeting and controlled lesion creation in deeper brain regions. Radiofrequency lesioning has long been used for several movement disorder targets, such as the ventral intermediate nucleus of the thalamus and GPi, and remains a significant treatment option for some individuals [11–14]. The pallidothalamic tract (PTT) is a principal efferent route of the GPi and is composed largely of fibres originating from the ansa lenticularis and lenticular fasciculus. These fibres converge in the subthalamic area, specifically in Forel's field H1, before projecting to the motor thalamus

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[19,22,23]. Excessive inhibitory signals from the GPi lead to dysfunctional basal ganglia-thalamocortical circuits in Parkinson's disease; hence, disrupting the pallidothalamic pathway offers a plausible surgical approach to diminish aberrant pallidal output [13,19,22]. In contrast to pallidotomy, which directly damages the GPi, pallidothalamic tractotomy aims to disrupt the primary pallidal efferent fibres while preserving the GPi's neuronal structure. The high anatomical density of these fibres in Forel's field H1 may offer a benefit by allowing a very small lesion to disrupt a functionally significant pathway. Anatomical research and clinical observations have identified the pallidothalamic area as a viable target for stereotactic intervention in movement disorders [19,22–27]. Initial clinical observations of pallidothalamic tractotomy showed improvement in Parkinson's disease motor symptoms, including tremor, rigidity, and hypokinesia [22]. Contemporary lesioning techniques, such as magnetic resonance-guided focused ultrasound (MRgFUS), have revitalized interest in the pallidothalamic tract as a potential therapeutic target. Clinical studies have demonstrated substantial improvements in motor function after unilateral or bilateral PTT, reinforcing the notion that disrupting this route might provide clinically relevant symptomatic relief for individuals with therapy resistant Parkinson's disease [24–26]. Despite the promise of these results, clinical research on PTT remains far less extensive than that on DBS and traditional GPi pallidotomy. Clinical data on stereotactic radiofrequency PTT remain limited, particularly regarding long-term motor outcomes and surgical complications. Furthermore, the pallidothalamic area requires careful evaluation because of its proximity to neighbouring structures, including the internal capsule, zona incerta, subthalamic region, and rednucleus, as well as sensory pathways.

The present prospective study was therefore designed to evaluate the clinical efficacy, durability, and safety of stereotactic radiofrequency pallidothalamic tractotomy in patients with medically refractory Parkinson's disease. The primary outcome was the change in motor function as assessed by the Unified Parkinson's Disease Rating Scale Part III (UPDRS-III), with particular emphasis on the medication-OFF state. Secondary outcomes included changes in contralateral rigidity, contralateral tremor, and Hoehn & Yahr stage, together with the assessment of postoperative complications and clinical recurrence during follow-up.

Materials and Methods

- **Study Design and Setting**

This prospective clinical study 34 patients, male 21 (61.8%), female 13 (38.2%) with median age 62 (table 1) was conducted at the Functional Neurosurgery Unit, Al-Sadr Teaching Hospital, Basra, Iraq from Feb. 2023 to Sep. 2025. Patients with medically refractory Parkinson's disease who underwent stereotactic radiofrequency pallidothalamic tractotomy were prospectively enrolled and followed clinically after surgery.

Table 1: Patient Demographic Characteristics

Characteristic	
Male, n (%)	21 (61.8%)
Female, n (%)	13 (38.2%)
Age, median [range]	62 [42–74]
Total	34

The study was conducted in accordance with the principles of the Declaration of Helsinki. Institutional ethical approval was obtained before commencement of the study, and written informed consent was obtained from all participants.

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- **Patient Selection**

Patients were selected for stereotactic radiofrequency pallidothalamic tractotomy (PTT) according to predefined clinical and surgical eligibility criteria.

- **Inclusion criteria**

Patients were eligible for inclusion if they met all of the following criteria:

- A clinical diagnosis of idiopathic Parkinson's disease according to established diagnostic criteria.
- A clear response to levodopa, defined as at least a 30% improvement in the Unified Parkinson's Disease Rating Scale (UPDRS) motor score.
- Persistent and disabling motor symptoms despite optimized medical therapy, including motor fluctuations, refractory rigidity, rigidity associated with tremor, or severe and disabling "off" periods.
- Positive functional response seen during the drug "on" phase, suggesting retained capacity for functional improvement post-surgery.
- Marked deterioration in daily life activities due to Parkinsonian motor manifestations.
- Clinical appropriateness for stereotactic ablative functional neurosurgery.
- Pragmatic anticipations about the possible advantages and constraints of surgical intervention.
- Readiness and capacity to adhere to postoperative clinical evaluations and subsequent monitoring.

- **Exclusion criteria**

Patients were excluded if they met any of the following criteria:

- Age >75 years.
- Atypical or secondary parkinsonism, including multiple system atrophy, progressive supranuclear palsy, corticobasal degeneration, or other Parkinson-plus syndromes.
- Poor or absent levodopa responsiveness.
- Severe disability or inadequate functional recovery during the medication "on" period.
- Severe cognitive impairment or dementia.
- Uncontrolled psychiatric illness, including active psychosis or severe depression, that could interfere with surgical treatment or postoperative assessment.
- Tremor-dominant symptoms without clinically significant rigidity, when the primary indication for PTT was not met.
- Active intracranial infection or systemic infection that contraindicated surgery.
- Significant coagulation abnormality or any medical condition representing a contraindication to stereotactic surgery.
- Previous ablative functional neurosurgery involving the intended surgical target.
- Inability or unwillingness to participate in the required postoperative follow-up assessments.

Surgical Planning

Anti-parkinsonian medications were withheld for approximately 8–12 hours before surgery to place patients in a relative medication-off state. This facilitated intraoperative neurological assessment and reduced medication-related motor fluctuations during stereotactic imaging and clinical testing.

- **Preoperative imaging**

Preoperative brain MRI was performed using a 1.5-T scanner according to a Brainlab-compatible stereotactic imaging protocol, either on the day of surgery or several days before the procedure, without the stereotactic frame in place. The imaging protocol included high-resolution axial and coronal T1-weighted sequences (Figure) 1, axial T2-weighted and fluid-attenuated inversion recovery (FLAIR) sequences, as well as diffusion-weighted imaging (DWI) with corresponding apparent diffusion coefficient (ADC) maps. For stereotactic

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planning and image fusion, thin contiguous slices with a thickness of 1 mm, without an interslice gap, were acquired. Detailed acquisition parameters, including repetition time (TR), echo time (TE), field of view, matrix size, and voxel dimensions, were standardized according to the institutional stereotactic imaging protocol. On the day of surgery, the Leksell stereotactic frame was securely attached to the patient's head under local anesthesia, followed by attachment of the fiducial indicator box. A stereotactic CT scan was subsequently obtained using thin contiguous slices ([X] mm) and fused with the preoperative MRI dataset within the Brainlab planning system. The fused MRI– CT images were used for stereotactic target localization, trajectory planning, and identification of critical adjacent anatomical structures. The stereotactic frame was positioned parallel to the CT scanning axis, with the gantry angle maintained at 0° to facilitate reconstruction of a three-dimensional cranial model.

The field of view was adjusted to include all fiducial markers. Thin-slice CT images, typically obtained at 0.6–1.25 mm intervals, extended from the base of the stereotactic frame through the superior aspect of the fiducial system. All procedures were performed using a Leksell stereotactic frame under local anesthesia with conscious sedation. The stereotactic CT dataset was co-registered with the preoperative MRI using Brainlab planning software. MRI–CT fusion was used to construct a three-dimensional stereotactic anatomical model and to determine the target and trajectory. The anterior commissure–posterior commissure (AC–PC) line was used as the principal stereotactic reference. Individualized trajectory planning was performed for each patient to minimize the risk of injury to cortical vessels, ventricles, the internal capsule, and other eloquent anatomical structures.

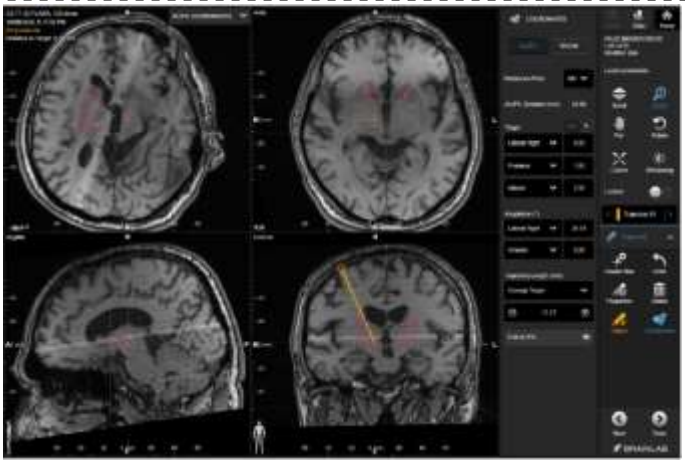


Figure 1: Stereotactic MRI-based surgical planning. High-resolution brain MRI obtained in axial, coronal, sagittal, and probe-view planes using a 1.5-T MRI scanner for localization of the intended PTT target and planning of the stereotactic trajectory.

- **Target Localization**

Because dedicated diffusion tensor imaging (DTI), tractography, or other direct pallidothalamic tract-mapping techniques were not routinely available at our center, target localization was performed using indirect anatomical targeting based on stereotactic MRI–CT fusion, established stereotactic atlases, and anatomical landmarks. The intended PTT target was localized indirectly within the anatomical region corresponding to Forel's field H1 using stereotactic MRI–CT fusion, stereotactic atlases, and identifiable adjacent anatomical landmarks The intended pallidothalamic tract (PTT) target was localized indirectly within the anatomical region corresponding to Forel's field H1, where pallidothalamic fibers converge before projecting toward the motor thalamus. Target localization was based on the relationship of the intended target to the anterior commissure–posterior commissure (AC–PC) reference system and identifiable adjacent anatomical structures. Reference target coordinates were approximately 1.8 mm posterior to the midcommissural point, 2–3 mm inferior to the intercommissural plane, and 9–13 mm lateral to the

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midline. Final target coordinates and trajectory were individualized according to each patient's stereotactic anatomy and the relationship of the planned target and trajectory to adjacent critical structures. Particular attention was given to the anatomical relationship of the intended lesion to the internal capsule laterally, the subthalamic nucleus inferiorly and posterolaterally, the zona incerta dorsally, the red nucleus posteroinferiorly, and the mammillothalamic tract medially. The planned target was positioned within the region of Forel's field H1 to achieve interruption of the pallidothalamic fibers while avoiding direct involvement of these adjacent structures. Postoperative imaging was used to confirm the location of the lesion within the intended PTT target region and to assess its anatomical relationship to the surrounding structures. Patient-specific final stereotactic coordinates, postoperative lesion dimensions, and lesion volume were not systematically recorded and are therefore not reported.

- **Surgical Procedure**

The procedure consisted of unilateral stereotactic radiofrequency lesioning of the PTT.

Subsequent to the administration of prophylactic antibiotics, the patient was placed in a supine posture to provide adequate comfort and cooperation throughout the surgical procedure. The skull was positioned so that the coronal suture reached its highest point, and the stereotactic device was securely attached to the operating table. Following the application of a povidone-iodine solution to the scalp, the specified infection site was located and indicated. The operation commenced with local anaesthesia, succeeded by the formation of a stereotactic burr hole and a parasagittal skin incision. Coagulation of the dura was necessary to minimise bleeding, and the stereotactic arc was adjusted to direct the electrode to the desired target. The burr hole was sealed with appropriate haemostatic substances and/or fibrin glue to minimize cerebrospinal fluid loss. The patient was closely observed to continuously assess tremors, voluntary movements, and neurological function throughout the procedure. The team maintained continuous intraoperative monitoring, including blood pressure and oxygen saturation. The team carefully controlled blood pressure, targeting a systolic reading below 140 mmHg. The surgical trajectory was selected to avoid cortical vessels, sulci, ventricles, and other critical structures. Following completion of lesioning, hemostasis was achieved, and the burr hole and wound were closed in layers with attention to prevention of cerebrospinal fluid leakage. The stereotactic frame was then removed. The wound was kept dry for approximately 48 hours, and sutures were removed approximately 7–10 days postoperatively.

- **Radiofrequency Lesioning**

After stereotactic placement of the electrode at the planned PTT target, macrostimulation as an intraoperative safety assessment for proximity to adjacent functional structures. Given the close anatomical relationship of the PTT to adjacent motor, sensory, and other eloquent pathways, stimulation was used to assess for unexpected neurological responses and to help identify proximity to adjacent critical structures, particularly the internal capsule and sensory pathways, before definitive lesion creation. A radiofrequency macroelectrode with a 2 × 2 mm uninsulated active tip was introduced through the stereotactic guide tube. Electrode impedance was monitored throughout the procedure using a temperature-controlled radiofrequency generator (Boston Scientific 4G system). After confirming the intended target, a preliminary test lesion was performed at 45°C for 30 seconds to assess for unexpected neurological effects and clinical response. In

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the absence of significant adverse effects, definitive radiofrequency lesioning was performed at 70°C for 40 seconds. Where considered necessary according to the planned lesion geometry, additional lesions were created along the same trajectory, with lesion sites separated by approximately 2 mm. One or two lesion points were used according to the intraoperative assessment and the desired extent of the target lesion.

- **Postoperative Imaging**

Routine postoperative noncontrast CT of the brain was obtained to assess for intracranial hemorrhage and other immediate postoperative complications and to document the general location of the stereotactic intervention. Precise postoperative localization of the radiofrequency lesion was not routinely attempted using CT because imaging artifacts may limit accurate visualization of the treatment lesion. Postoperative MRI (Figure 2) was subsequently performed to assess the radiological appearance and temporal evolution of the treatment-related abnormality, as described below.

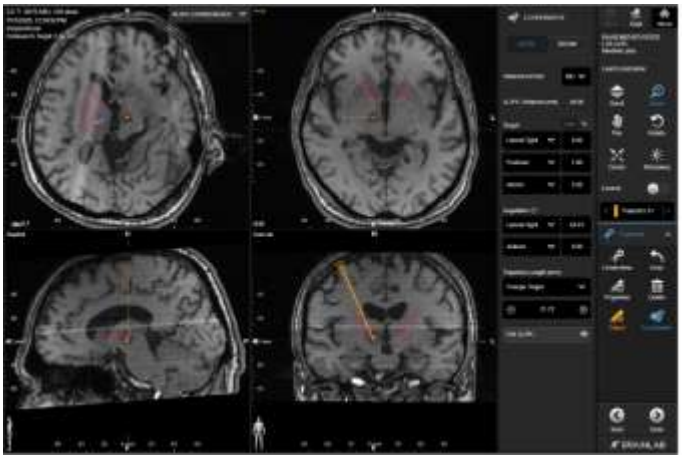


Figure 2: Stereotactic MRI-based planning and localization of the intended PTT target and trajectory.

Safety Outcomes

Postoperative complications were prospectively recorded, including:

- Intracerebral hemorrhage
- Stroke
- Seizure
- Headache
- Numbness or tingling
- Facial or limb weakness
- Speech disturbance
- Balance disturbance
- Clinical recurrence

Postoperative MRI Follow-up

Postoperative MRI was performed to evaluate the immediate radiological effects of stereotactic PTT lesioning and their subsequent evolution. T1-weighted axial (Figure 3) and coronal images (Figure 4) obtained on the first postoperative day demonstrated a focal postoperative signal abnormality centered at the intended PTT target and extending along the planned treatment trajectory. At three months postoperatively, follow-up MRI (Figures 3 and 4) demonstrated marked interval reduction in the conspicuity of the previously observed signal abnormality. No significant perilesional edema, intracranial hemorrhage, mass effect, or other acute structural abnormality was identified. These serial imaging findings demonstrated temporal evolution of the postoperative MRI appearance following radiofrequency PTT lesioning.

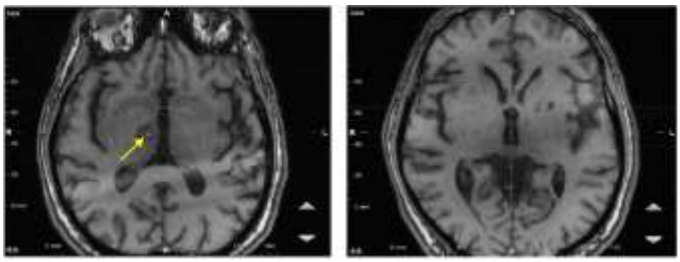


Figure 3: Temporal evolution of the postoperative MRI appearance following stereotactic PTT lesioning.

(A) Axial T1-weighted MRI obtained on the first postoperative day demonstrates a focal postoperative signal abnormality centered at the intended PTT target (yellow arrow).

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(B) Three-month follow-up axial T1-weighted MRI demonstrates marked interval reduction in the conspicuity of the postoperative signal abnormality at three-month follow-up.

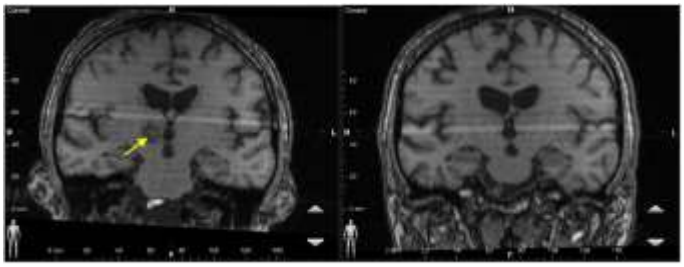


Figure 4: Coronal MRI appearance following stereotactic PTT lesioning. (A) Coronal T1-weighted MRI obtained on the first postoperative day demonstrates a focal postoperative signal abnormality at the intended PTT target (yellow arrow).

(B) Three-month follow-up coronal MRI demonstrates marked interval reduction in the conspicuity of the previously observed postoperative signal abnormality.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Preoperative and postoperative UPDRS-III scores, contralateral rigidity, contralateral tremor, and Hoehn and Yahr stage were compared using appropriate paired statistical tests according to the distribution and measurement characteristics of the data. The percentage improvement from baseline was calculated for each clinical outcome. A two-sided p value < 0.05 was considered statistically significant.

Results

At one month following surgery, all evaluated clinical outcomes demonstrated substantial improvement compared with preoperative values. These improvements were maintained or further enhanced at the one-year follow-up.

The UPDRS-III OFF score (Table 2) decreased from 42.4 ± 5.4 preoperatively to 20.2 ± 4.2 at one month, representing a 52.4% improvement from baseline. At one year, the mean UPDRS-III OFF score further decreased to 18.1 ± 3.6, corresponding to a 57.3% improvement compared with the preoperative value ($p < 0.001$). Regarding the contralateral side of surgery, the average rigidity score decreased from 3.25 ± 0.64 before to surgery to 1.20 ± 0.52 after one month, indicating a 63.1% enhancement. After one year, the score decreased to 0.75 ± 0.49, reflecting a 76.9% enhancement from the baseline ($p < 0.001$). For contralateral tremor improved markedly postoperatively. The mean score decreased from 3.00 ± 0.73 preoperatively to 0.82 ± 0.75 at one month, a 72.7% improvement. At one year, the mean score was 0.65 ± 0.65, a 78.3% improvement from baseline ($p < 0.001$). The Hoehn & Yahr stage (Table 2) also demonstrated significant functional improvement. The mean stage decreased from 2.83 ± 0.29 preoperatively to 1.64 ± 0.22 at one month, representing a 42.0% improvement. At one year, the mean stage decreased further to 1.08 ± 0.18, corresponding to a 61.8% improvement from baseline ($p < 0.001$). Overall, the postoperative results demonstrated statistically significant improvement across all assessed motor and functional outcomes. The response was evident as early as one month after surgery and was maintained or further improved at one year. The greatest longterm improvement was observed for contralateral tremor (78.3%), followed by contralateral rigidity (76.9%), Hoehn & Yahr stage (61.8%), and UPDRS-III OFF (57.3%). All postoperative improvements were statistically significant ($p < 0.001$).

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Table 2: preoperative and postoperative assessments

Outcome	Assessments			% Improvement		p-value
	Preoperative	One month postop.	One year postop.	One month vs. Pre-op	One year vs. Pre-op	
UPDRS-III OFF	42.4 ± 5.4	20.2 ± 4.2	18.1 ± 3.6	52.4%	57.3%	<0.001
Contralateral rigidity	3.25 ± 0.64	1.20 ± 0.52	0.75 ± 0.49	63.1%	76.9%	<0.001
Contralateral tremor	3.00 ± 0.73	0.82 ± 0.75	0.65 ± 0.65	72.7%	78.3%	<0.001
Hoehn & Yahr stage	2.83 ± 0.29	1.64 ± 0.22	1.08 ± 0.18	42.0%	61.8%	<0.001

Postoperative Complications

Most reported postoperative symptoms were transient or mild, and no procedure-related mortality was observed. No intracerebral hemorrhage, stroke, or seizure was observed (Table 3).

Table 3: Postoperative Complications Following PTT

Complication	PTT (n=34)
Recurrence	0 (0%)
Intracerebral hemorrhage	0 (0%)
Stroke	0 (0%)
Seizure	0 (0%)
Headache	19 (55.9%)
Numbness/tingling	1 (2.9%)
Facial/arm weakness	2 (5.9%)
Speech disturbance	1 (2.9%)
Balance disturbance	2 (5.9%)

Discussion

Clinical Outcomes

Pallidotomy is the most widely available lesioning surgery for dystonia[27-29], and we recently reported on the efficacy of lesioning on the pallidothalamic tract for dystonia [30,31]. The present prospective study evaluated stereotactic radiofrequency pallidothalamic tractotomy in 34 patients with medically refractory Parkinson's disease. The present study demonstrated substantial and sustained clinical improvement following stereotactic radiofrequency pallidothalamic tractotomy (PTT) in patients with medically refractory Parkinson's disease [29]. We observed significant improvements across all evaluated motor and functional outcomes at both the one-month and one-year follow-ups. The average UPDRS-III OFF score decreased by 52.4% after one month and by 57.3% after one year, indicating a significant enhancement in total motor impairment. The continued presence of this reaction after one year indicates that PTT's advantageous impact extended beyond the immediate postoperative phase. The further decrease in the average UPDRS-III OFF score from one month to one year may suggest ongoing stabilisation or improvement of the clinical advantage over time. The effects on the principal motor symptoms were very substantial. Contralateral stiffness exhibited a 63.1% improvement at one month and a 76.9% improvement at one year, while contralateral tremor showed improvements of 72.7% and 78.3%, respectively. These results indicate that PTT may significantly regulate both stiffness and tremors, with the degree of enhancement sustained or even augmented throughout extended follow-up. The stronger response in these motor symptoms, compared with the overall UPDRS-III score, may suggest a direct influence on pallidothalamic output pathways involved in motor regulation. The global severity of the illness, evaluated using the Hoehn and Yahr stage, shown significant improvement, reducing from 2.83 ± 0.29 preoperatively to 1.64 ± 0.22 at one month and 1.08 ± 0.18 at one year. This reflects enhancements of 42.0% and 61.8%, respectively. The gradual improvement shown after one year aligns with the enduring motor advantages evidenced by the UPDRS-III and specific motor symptom evaluations. All assessed results showed statistically significant enhancement after surgery ($p < 0.001$). These results indicate that PTT may provide significant and lasting improvements in motor capabilities and overall disease severity in well-chosen individuals with medication resistant Parkinson's disease. Maintaining the advantages beyond a single year is particularly important, since

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durability is an essential criterion in evaluating lesion-targeted functional neurosurgical procedures.

Postoperative Complications and Safety

This cohort had a positive postoperative complication profile. Among the 34 individuals who had PTT, there were no occurrences of recurrence, intracerebral haemorrhage, stroke, or seizure. The lack of severe outcomes such as cerebral haemorrhage, vascular injury, seizures, and harm to adjacent functioning tissues is significant, considering the potential risks associated with stereotactic lesioning procedures. At 19 patients (55.9%), headache was the most frequently reported postoperative symptom. This comparatively high frequency should not be interpreted as a target-specific neurological problem, but rather in the context of stereotactic frame alignment and the perioperative procedure. In contrast, focal neurological complications were uncommon. Facial or arm weakness occurred in 2 patients (5.9%), balance disturbance in 2 patients (5.9%), while numbness/tingling and speech disturbance occurred in 1 patient each (2.9%). The low incidence of balance disturbance and focal motor or sensory deficits is clinically relevant given the close anatomical relationship between the pallidothalamic region and neighboring motor pathways. No intracerebral hemorrhage or clinically apparent postoperative stroke was observed in this cohort study. Importantly, no recurrence was observed during the follow-up period, while significant improvement in UPDRS-III OFF, rigidity, tremor, and Hoehn and Yahr stage was maintained at one year. Thus, the observed clinical benefit was accompanied by a low incidence of serious neurological complications. Overall, the combination of substantial and sustained clinical improvement with a favorable safety profile supports PTT as a potentially effective lesioning procedure for medically refractory Parkinson's disease. However, the present findings should be interpreted with consideration of the relatively small sample size of 34 patients. More extensive prospective research with prolonged follow-up and uniform evaluation of the length and intensity of postoperative problems is necessary to validate the long-term effectiveness and safety of PTT.

Limitations

This study has several limitations. First, the sample size was relatively small, comprising 34 patients. Second, the study was conducted at a single center, which may limit generalizability. Third, extended follow-up is needed to determine whether clinical advantages are sustained. Fourth, the lack of a simultaneous control group inhibits direct statistical comparison with GPi pallidotomy or DBS.

Ultimately, future research must include standardised evaluations of quality of life, dyskinesia, gait and postural instability, levodopa equivalent daily dosage, and independent blinded UPDRS assessments.

Conclusion

Stereotactic radiofrequency pallidothalamic tractotomy (PTT) shown significant and enduring improvement in motor capabilities and disease intensity in individuals with medically resistant Parkinson's disease. At the one-month mark, patients exhibited significant decreases in UPDRS-III OFF scores, contralateral stiffness, contralateral tremor, and Hoehn & Yahr stage, with these improvements sustained or enhanced at the one-year point ($p < 0.001$). There were no instances of intracerebral haemorrhage, stroke, seizure, or recurrence that were reported throughout the follow-up period, indicating that the surgery had a favorable safety profile. Most adverse events after surgery were modest, with headaches the most commonly reported symptom. In contrast, specific neurological problems were extremely rare. These results imply that PTT may offer a successful,

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persistent, and reasonably safe lesioning alternative for individuals with Parkinson's disease who have been carefully chosen and are medically refractory. This is especially true for patients who have substantial stiffness and tremor. To evaluate the long-term efficacy, sustainability, and safety of this intervention, it is important to conduct larger prospective trials with extended follow-up periods.

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