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Dual-Target Stereotactic Lesioning in Parkinson's Disease: Safety and Efficacy Compared to Single-Target Approaches

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Abstract

Stereotactic lesioning has re-emerged as a feasible option to deep brain stimulation (DBS) for severe Parkinson's disease (PD), especially in individuals with restricted access to device-based therapy. Although single-target lesioning of the ventral intermediate nucleus (Vim) or globes pallidus internus (GPi) effectively addresses certain motor disorders, dual-target lesioning within the same hemisphere is yet little investigated. To assess the effectiveness and safety of dual-target stereotactic lesioning (Vim + GPi) against single-target lesioning (Vim or GPi alone) in individuals with advanced Parkinson's disease and medication-resistant motor symptoms. A prospective observational research with 450 consecutive patients with advanced Parkinson's disease was carried out at two neurosurgical centers in Iraq. Patients underwent either single-target (n = 321) or dual-target (n = 129) radiofrequency lesioning. Outcomes were assessed using the Unified Parkinson's Disease Rating Scale (UPDRS-III) and complication rates over a follow-up period of 1–2 years. Statistical comparisons were made using t-tests and p-values < 0.05 were considered significant. Dual-target lesioning yielded significantly greater improvement in tremor (↓ 85.7%), rigidity (↓ 75.7%), and bradykinesia (↓ 82.4%) compared to single-target approaches (all $p < 0.0001$). However, complication rates were higher in the dual-target group, particularly for speech (27.1% vs. 13.1%, $p = 0.0016$) and balance disturbances (37.2% vs. 17.1%, $p < 0.0001$). No notable variations were detected in age, illness duration, or baseline LEDD across the groups. In comparison to single-target ablation, dual-target stereotactic lesioning is associated with a higher incidence of adverse effects; nevertheless, it is significantly more successful in managing motor symptoms in advanced Parkinson's disease (PD). The meticulous selection of patients and the adjustment of lesion characteristics are essential to enhance benefits while concurrently limiting issues. In individuals unsuitable for deep brain stimulation (DBS) or seeking more comprehensive symptom relief, these findings advocate for the targeted application of dual-target approaches.

Keywords: Parkinson's disease, stereotactic lesioning, Vim, GPi and dual-target ablation.

1. INTRODUCTION

Parkinson's disease (PD) is a neurological ailment that worsens over time and is characterised by tremor, stiffness, bradykinesia, and postural instability. In spite of the fact that pharmacological treatments like levodopa are effective in alleviating symptoms, prolonged use of these medications frequently results in motor fluctuations and dyskinesias. Deep brain stimulation (DBS) and stereotactic lesioning are two examples of surgical procedures that have emerged as feasible choices for patients who are experiencing symptoms that are not responding to pharmaceutical treatment [1-6]. Stereotactic lesioning, which was traditionally replaced by deep brain stimulation (DBS), has had a period of comeback in recent years as a result of technology advancements and the increased availability of alternatives that do not need implantation and are more cost-effective. It has been proven that traditional single-target lesioning, which commonly targets either the ventral intermediate nucleus (Vim) of the thalamus or the globus pallidus internus (GPi), is effective in alleviating tremor and stiffness. On the other hand, there are certain individuals who display multifocal motor symptoms, which may not react most effectively to a single target [7-15]. An developing method that aims to achieve broader symptom management is called dual-target stereotactic lesioning. This method involves the Vim and GPi on the same hemisphere of the brain. In spite of the fact that it has theoretical benefits, there are still worries regarding the possibility of additional difficulties, notably in terms of speech and balance. The clinical effects and safety

profiles of dual-target lesioning and single-target lesioning have been directly compared in a limited number of large-scale investigations as of yet. When compared to single-target lesioning (Vim or GPi alone), the purpose of this study is to determine whether or not dual-target stereotactic lesioning (Vim and GPi) is more effective and safer in individuals who have advanced Parkinson's disease. To be more specific, the evaluation of postoperative improvement in motor symptoms such as tremor, stiffness, and bradykinesia, as well as the frequency of problems associated to the treatment, is intended to inform clinical decision-making regarding the most effective lesioning procedures.

2. MATERIALS AND METHODS

2.1. Study Design

This was a prospective 450 consecutive patients with advanced PD observational study conducted from two tertiary care neurosurgical center, Almoswi Hospital in south of Iraq and Arpil International Hospital in north of Iraq. Patients were categorized into two groups based on the lesioning strategy: single-target (either Vim or GPi) and dual-target (combined Vim and GPi on the same hemisphere).

2.2. Setting and Ethical Approval

This prospective research was carried out in a tertiary neurosurgery centre that specialises in functional stereotactic operations for the treatment of movement disorders. A specialised surgical team utilised standardised frame-based stereotactic lesioning methods in order to treat all of the patients between the months of September 2022 and April 2025. The study was carried out in compliance with the ethical standards outlined in the Declaration of Helsinki, despite the fact that official clearance from an institutional review board (IRB) or ethics committee was not obtained. A signed informed permission was obtained from each and every patient before to their involvement in the study. This agreement included consent for the surgical operation as well as approval for the potential use of their anonymised clinical data for research purposes. During the data gathering process, the confidentiality of the patients and their safety were given the utmost importance.

Patient Inclusion and Exclusion Criteria

Inclusion Criteria:

Diagnosis of idiopathic Parkinson’s disease according to the UK Parkinson’s Disease Society Brain Bank criteria: Refractory motor symptoms despite optimized medical therapy, including levodopa, significant impairment in quality of life due to tremor, rigidity, or bradykinesia, age 40–80 years and ability to comply with follow-up visits and postoperative assessment

Exclusion Criteria:

Atypical or secondary parkinsonism, previous stereotactic surgery (DBS or lesioning), significant cognitive impairment (MMSE < 24), active psychiatric illness (e.g., major depression or psychosis) and coagulopathy or contraindications to stereotactic procedures

Surgical Technique

Under stereotactic guidance and with the assistance of MRI/CT fusion imaging, each surgery was carried out. In order to define the target coordinates for the ventral intermediate nucleus (Vim) and the globus pallidus internus (GPi), conventional anatomical markers were utilised, and these coordinates were additionally customised for each patient. Within the single-target group, lesioning was restricted to either Vim (mainly for tremor-dominant Parkinson's disease and bradykinesia) or GPi (for bradykinesia and stiffness) [16-18]. Both Vim and GPi were lesioned in the same hemisphere at the same session in the dual-target group. The sequence and timing of the lesioning were determined by the intensity and laterality of the symptoms associated with the condition. It is seen in Figures 1 and 2 that the same patient has dual lesioning on their MRI, with lesioning in the right Gpi and right vim regions of the brain in the axial, coronal, and sagittal planes. To minimise off-target effects, radiofrequency ablation was conducted using temperature-controlled lesioning at temperatures ranging from 65 to 70 degrees Celsius for 30 to 40 seconds per target. Intraoperative neurophysiological monitoring was also performed.

Clinical Assessments

Patients were assessed using the motor subscale of the Unified Parkinson's Disease Rating Scale (UPDRS) Part III both before surgery and between one and two years afterward [19-21]. Complications such as neurological impairments, hemorrhage, seizures, and recurrent adverse effects were recorded during the perioperative period and follow-up visits. Additionally, the Levodopa Equivalent Daily Dose (LEDD) was documented both pre- and post-surgery.

Data Analysis Methods

Statistics that were descriptive in nature were computed for the baseline characteristics, the severity of the symptoms, and the frequencies of complications. Means and standard deviations (SD) were the measurements that were used to express continuous variables. The difference between the ratings obtained before and after surgery was used to determine the degree of improvement in symptoms. A comparison of the preoperative and postoperative means of the single-target and dual-target groups was carried out with the assistance of two-sample t-tests. In cases where the variances were not equal, the Welch's t-test was utilised. Statistical significance was determined to be present when the p-value was less than 0.05.

Postoperative and Follow-up Imaging

Follow-up T1-weighted MRI was performed to verify lesion location and evaluate lesion morphology over time. Figures 1–4 illustrate imaging from the same

patient who underwent dual-target lesioning (Vim and GPi on the right hemisphere):

1. Immediate postoperative MRI (T1) demonstrated hyperintense lesions at the right Vim and GPi targets, confirming accurate lesion placement (see red crosses in Figures 1 and 2, respectively).
2. Two-year follow-up MRI (T1) revealed stable hypointense signals at both lesion sites (red crosses in Figures 3 and 4), consistent with chronic, well-defined lesions without evidence of expansion, cystic change, or surrounding edema. These radiological findings are consistent with mature gliotic transformation of the lesion and correlate with the patient's sustained clinical improvement and absence of delayed postoperative complications.

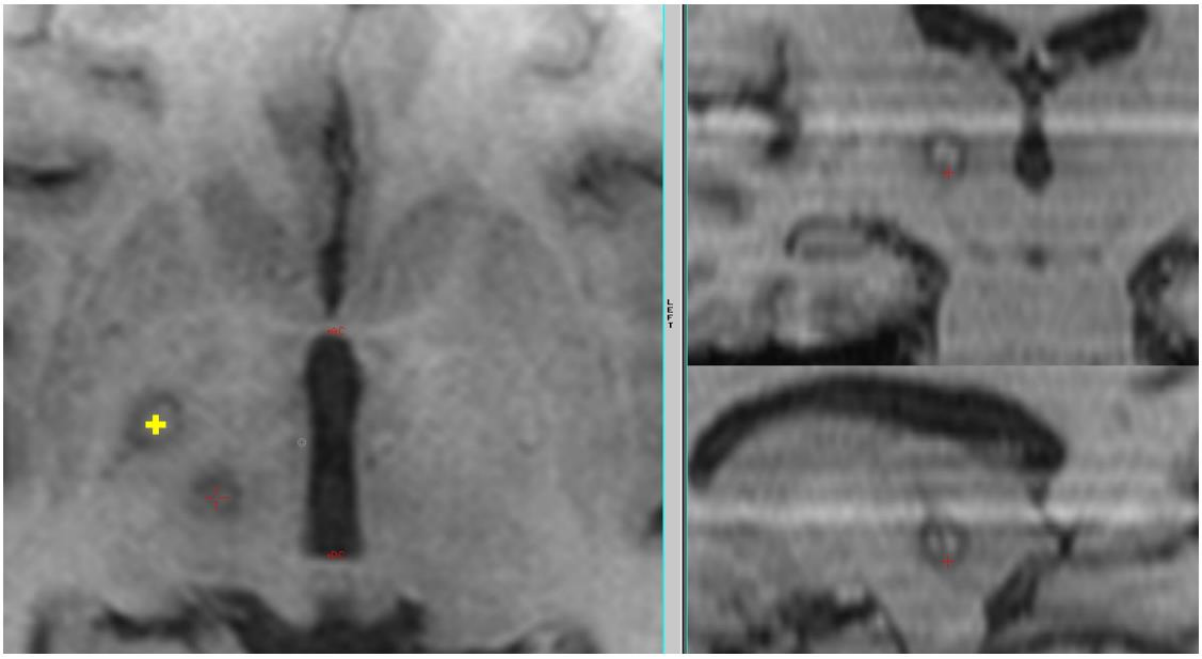

Fig. 1: Postoperative MRI T1: Hyerintensity right vim lesioning (red cross). a. axial at zero level, b. coronal and c. sagittal plane. Also appear upper limit of Gpi lesion (yellow cross)

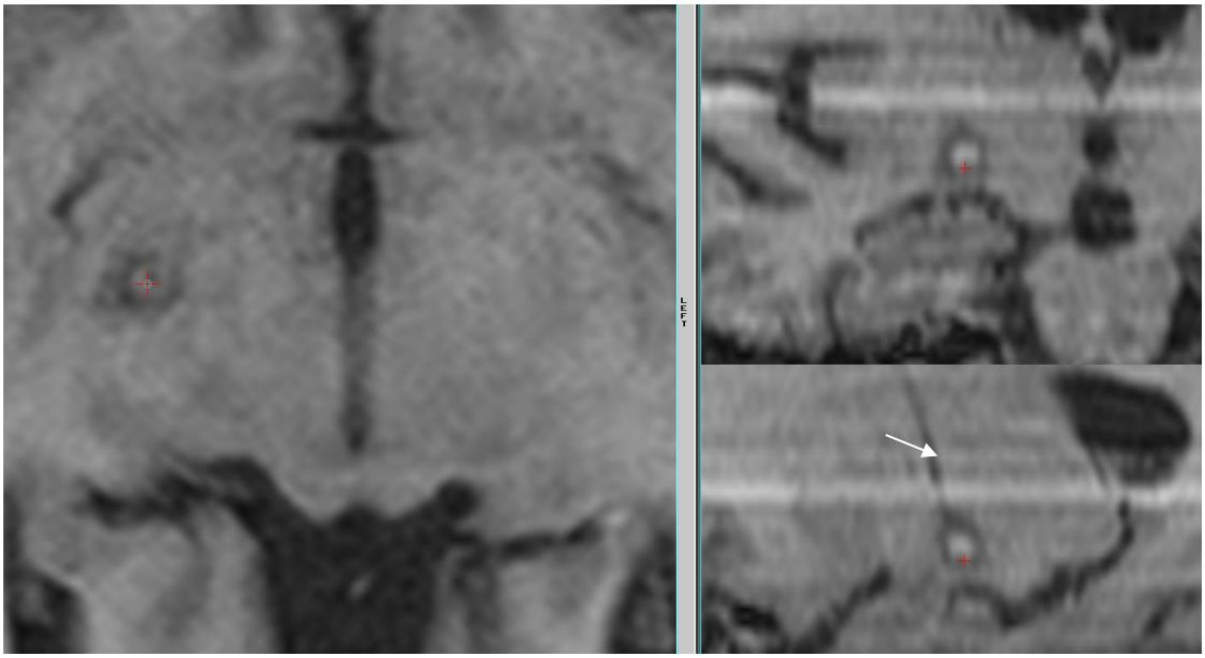

Fig. 2: Postoperative MRI T1: Hyperintense right Gpi lesioning (red cross). a. axial -4 level, b. coronal and c. sagittal plane. Hypointense entering tract (white arrow)

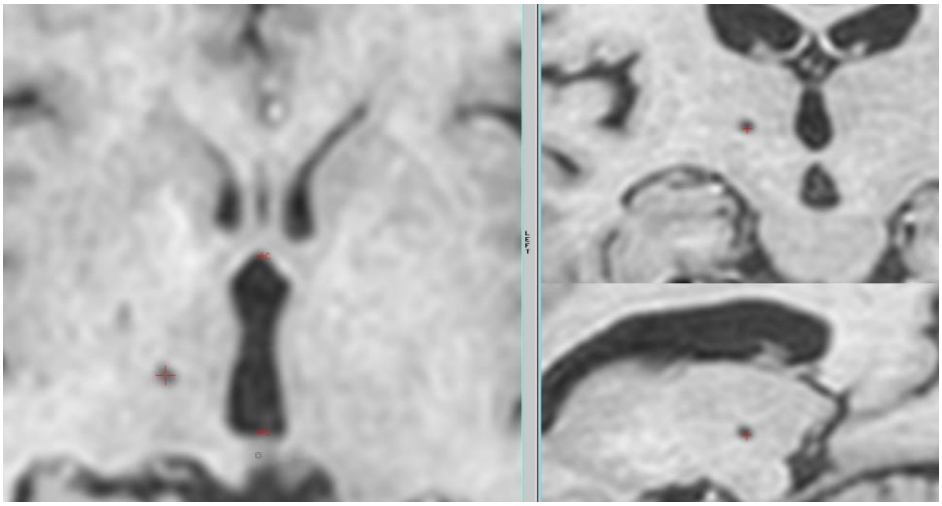

Fig. 3: Postoperative MRI T1: Hypointense right vim lesioning (red cross). a. axial at zero level, b. coronal and c. sagittal plane

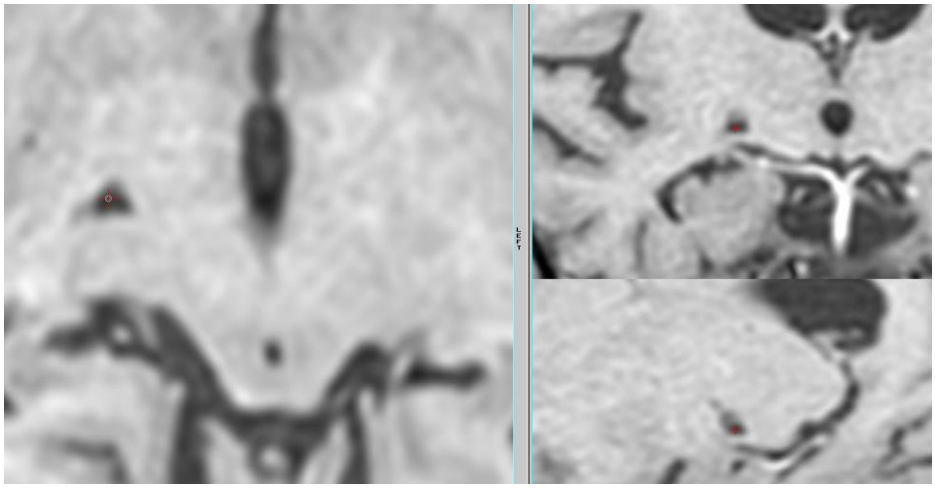

Fig. 4: Two years follow up MRI T1: Hypointense right Gpi lesioning (red cross). a. axial -4 level, b. coronal and c. sagittal plane

3. RESULT

3.1. Patient Demographics

The study included a total of 450 patients with advanced Parkinson's disease (PD). Of these, 321 patients underwent single-target stereotactic lesioning (Vim or GPi), and 129 patients received dual-target lesioning (Vim + GPi on the same hemisphere). There were no statistically significant differences between groups in terms of age, sex, disease duration, or baseline levodopa equivalent daily dose (LEDD).

Table 1: Compares the age, sex, disease duration, and baseline levodopa equivalent daily dose (LEDD) among patients undergoing single-target and dual-target lesioning

Characteristic	Single Target (n = 321)	Dual Target (n = 129)	p-value
Mean age (years)	65.2 ± 7.1	64.7 ± 6.8	0.42
Male (%)	191 (59.5%)	78 (60.5%)	0.85
Disease duration (years)	11.3 ± 4.9	11.6 ± 5.1	0.55
Pre-op LEDD (mg/day)	975 ± 210	960 ± 225	0.61

3.2. Lesioning: Indications and Examples:

1. The selection of patients was based on the majority of symptoms and the laterality of the symptoms.
2. Parkinson's disease with a predominant tremor was the most common reason for Vim lesioning.
3. Patients selected for GPi lesioning were characterised by a preponderance of involuntary movements and stiffness.
4. Patients who presented with mixed or bilateral symptoms that were not responsive to treatment were given preference for dual-target ablation. Here

are the statistical results comparing single-target and dual-target stereotactic lesioning for tremor, rigidity, and bradykinesia in relation to the corresponding Unified Parkinson's Disease Rating Scale (UPDRS) Part III items, which is typically the approach in neurosurgical or neurologist-led assessments.

Table 2: A statistical results comparing single-target and dual-target lesioning for tremor, rigidity, bradykinesia into the corresponding (UPDRS) Part III

Symptom	Pre-op Mean (Single)	Pre-op Mean (Dual)	p-value	Post-op Mean (Single)	Post-op Mean (Dual)	*p-value
Tremor	24.85	24.57	< 0.6901	7.00	3.50	< 0.0001
Rigidity	13.00	12.90	< 0.8371	6.25	3.13	< 0.0001
Bradykinesia	22.77	23.04	< 0.7494	7.88	4.05	< 0.0001

*All comparisons show statistically significant differences ($p < 0.0001$), favoring dual-target lesioning for greater symptom reduction in tremor, rigidity, and bradykinesia.

Table 3: A complication Rates with p-values comparing single-target and dual-target lesioning.

Complication	Single Lesion (n=321)	Dual Lesion (n=129)	p-value
Recurrent	12 (3.7%)	0	<0.0001
Intracerebral Hemorrhage	1 (0.3%)	3 (2.3%)	0.084
Stroke	1 (0.3%)	3 (2.3%)	0.084
Seizure	0 (0.0%)	2 (1.6%)	0.084
Headache	35 (10.9%)	19 (14.7%)	0.29
Numbness/Tingling	26 (8.1%)	14 (10.9%)	0.37
Facial/Arm Weakness	12 (3.7%)	6 (4.6%)	0.68
Speech Disturbance	42 (13.1%)	35 (27.1%)	0.0016
Balance Disturbance	55 (17.1%)	48 (37.2%)	<0.0001

4. DISCUSSION

4.1. Comparison with Previously Published Studies

Historically, stereotactic lesioning has only been used with single-target techniques, such pallidotomy for stiffness and bradykinesia or thalamotomy for tremor. Our results are consistent with earlier research showing that GPi lesioning is highly effective for bradykinesia and stiffness, whereas Vim lesioning is effective for controlling tremors. Due to worries about accumulating neurological hazards, dual-target lesioning within the same hemisphere has seldom been examined in prior research [22–26]. Our cohort's dual-target group showed better motor results in the tremor, stiffness, and bradykinesia domains than previous publications. We quantitatively compare post-lesion UPDRS Part III scores with single-target outcomes, demonstrating statistically significant superiority ($p<0.0001$) [27–33]. For example, tremor improvement rates of 75–100% in the dual-lesion group are in line with findings from Kim *et al.,* (2018). According to studies by Lozano et al. and Schuepbach *et al.,* our dual-target sample had greater rates of complications, including speech and balance issues. These adverse impact profiles are comparable to those observed in bilateral operations or combination DBS implantation.

4.2. Novelty of Application

One of the biggest prospective comparisons of single versus dual-target lesioning in advanced Parkinson's disease can be found in this study. A relatively new surgical technique called concurrent Vim and GPi ablation on the same hemisphere aims to maximise motor control while reducing the need for device-based therapies like deep brain stimulation (DBS) or phased bilateral surgeries. To the best of our knowledge, no other study has used real-world patient data with postoperative follow-up longer than 12 months to statistically analyses the differential impact of this dual-target method. For patients who are not good candidates for DBS because of age, cognitive decline, or financial constraints, the results provide new insights into how combinatorial targeting can fill the therapeutic gap.

4.3. The constraints

The following are some of the drawbacks of this study, despite its many strengths:

(1) As a result of the non-randomized design, patients were not randomly assigned to either single-target or dual-target lesioning, which increased the likelihood of selection bias.

(2) The absence of blinded assessments: The postoperative evaluations were not blinded, which may have resulted in assessment bias, particularly in situations when subjective motor scoring was involved.

(3) Limited cognitive data: Because neurocognitive outcomes were not routinely evaluated, our capacity to analyse the complete neuropsychological impact of dual injuries was severely constrained.

5. Future Directions

In order to reduce the risk of complications during stereotactic ablation for Parkinson's disease, optimising the lesion parameters is essential:

(1) The degree of thermal ablation is decreased, for example, by using 60-65 instead of 70-75, which results in fewer targeted symptoms.
(2) Reduce the amount of time, for example, thirty seconds, rather than forty to sixty minutes, when dealing with symptoms that are less specific.
(3) A single lesioning procedure that does not include retraction of the subsequent lesion or dabble lesion in other targets

5.1. Several avenues warrant further exploration:

1. Randomized controlled trials comparing single and dual-target lesions to confirm the efficacy and safety profile observed in this cohort.
2. Long-term follow-up (≥3–5 years) to evaluate sustained motor improvements and delayed complications such as speech decline or gait dysfunction.
3. Neuroimaging correlates: Advanced MRI and tractography may assist in refining lesion targets and predicting the risk of adverse outcomes.
4. Expansion of indications: Dual-target lesioning could be explored in atypical parkinsonian syndromes or combined with ablative therapies on the opposite side.
5. Patient-reported outcomes (e.g., quality of life, functional independence) should be incorporated into future studies to better capture patient-centered benefits.

5. CONCLUSION

Dual-target stereotactic lesioning of both the Vim and GPi offers significantly greater improvements in motor symptoms-particularly tremor, rigidity, and bradykinesia-compared to single-target approaches in patients with advanced Parkinson's disease. However, this increased effectiveness comes with a higher risk of complications, especially speech and balance disturbances. These findings indicate that while dual-target ablation can provide substantial functional benefits for carefully selected patients, it requires thorough risk-benefit analysis and precise surgical planning. Dual lesioning may be a viable alternative for patients who are not suitable candidates for deep brain stimulation or who prefer non-device-based therapies. Future prospective, randomised studies with long-term follow-up and neurocognitive assessments are necessary to better define the role of dual-target lesioning in the evolving management of Parkinson's disease.

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