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Stereotactic Ablative Surgery For Movement Disordres

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ORIGINAL ARTICLE

Stereotactic Ablative Surgery for Movement Disorders

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Abstract

Background: **Since its inception in the early 1950s, the radiofrequency (RF) ablative technique has served a crucial function in the treatment of movement problems. Ablative surgery is encouraging since it does not require substantial perioperative care, does not run the risk of hardware issues, and it costs less than deep brain stimulation.**

Aim of the work: **This study is to evaluate the efficacy and safety of RF ablative surgery for medically intractable movement disorders.**

Patients and methods: **This study was conducted retrospectively on 20 patients with medically refractory movement disorders who had undergone macrostimulation-guided RF ablative surgery in the institutions affiliated with Al-Azhar University between December 2018 and March 2021.**

Results: **Thirty-five radiofrequency ablative treatments were performed on twenty patients, with an overall average age of 53.75 years, including 13 male and 7 female patients. There was a noticeable improvement in the contralateral rigidity (68.24 %), tremors (84.29 %), and bradykinesia (75.36 %), bringing the overall UPDRS−III−off stage from pre-op 46.11 to post-op 14.89. The BFMDRS total movement score improved from a mean 46.5 prior to surgery to 29 one month later, representing a 37.63 % improvement. Additionally, the disability score decreased from 14.25 prior to surgery to 11, which represents a 22.8 % improvement.**

Conclusions: **For carefully chosen PD patients with no additional risk, the combination of macrostimulation-guided unilateral Vim thalamotomy and PVP technique looks like to be an acceptable and cost-effective treatment for patients with tremor, rigidity, and bradykynesia who are refractory to medical treatment.**

Keywords: Dystonia, Macrostimulation, Pallidotomy, Parkinsonism, Thalamotomy

1. Introduction

Movement disorders like dystonia, tremor and Parkinson's disease (PD) are among the most prevalent neurological illnesses. If these conditions become medically intractable, functional neurosurgery is crucial in their management.[1]

Human stereotactic surgery was first used in 1947 by Spiegel and Wycis. The stereotactic procedures assist in reaching many targets without surgical visual control. Three coordinates—lateral, anteroposterior, and vertical—define a stereotactic target (x, y, and z).[2] Ablative therapy for neurological conditions try to selectively destroy a specific area of cerebral tissue. Therapeutic brain lesions disrupt maladaptive neural networks or remove aberrant tissue, such as brain tumor.[3]

The four primary ablative methods utilised today are laser interstitial thermal treatment (LITT), stereotactic radiosurgery (SRS), high-intensity focused ultrasound (HIFU) thermal ablation, and radiofrequency (RF) thermoablation.[4] Of these methods, the RF ablation has continued to be widely used and effective. The margins of RF lesions are well-circumscribed, and the RF lesion's size and shape can be controlled more precisely.[5]

Ablative operations have a number of benefits, including less postoperative care, a lower risk of hardware issues such skin erosions, infections, fractures, and material malfunctions that could result in

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potentially fatal situations, as well as a lower cost than DBS.[6] However, because to the high-frequency of side effects linked to bilateral lesions, it is only permitted for unilateral surgeries (thalamic or pallidal). Dysphagia, cognitive deficits, hypophonia, aphasia and dysarthria are some of the negative effects of bilateral lesioning that have been reported.[7]

2. Patients and methods

A retrospective analysis with 20 patients was conducted. Who had undergone RF ablative surgery at Al-Azhar university hospitals between December 2018 and March 2021 and had medically intractable movement disorders.

This series includes eighteen PD patients and two GD patients transferred from the Neurology Clinic in Al- Azhar University Hospitals after failure of medical treatment to achieve satisfactory results and development of intolerable side effects.

2.1. Inclusion criteria

Patients with all genders and age groups diagnosed with medically intractable movement disorder for at least three years duration.

2.2. Exclusion criteria

Unstable medical condition precluding awake stereotactic surgery, patients with movement disorders for less than three years, patients who do not manifest a significant reduction with dopaminergic medications with the exception of tremor, patients with 2^{ry} movement disorder except for posttraumatic Parkinsonism, patients with Parkinson-plus syndromes, patients with severe cognitive dysfunction or significant dementia, severe postural instability, patients with increased risk of intracerebral hemorrhage.

2.3. Evaluation tools

Parkinson patients were evaluated using the recommendations of the Core Assessment Programme for Surgery Interventional Treatments in Parkinson's disease (CAPSIT-PD). The Unified Parkinson's Disease Ranking Sale Motor Score (UPDRS−III−off stage) (0−108) is the primary evaluation scale. Prior to surgery, the first postoperative day, and six months afterwards, the patients were evaluated.[8]

The patients with GD were assessed using the Burke-Fahn-Marsden Dystonia Rating Scale (BFMDRS) prior to surgery, on the first postoperative day, and at the most recent follow-up, which was one month later. The score for the BFMDRS goes from 0 (the lowest/best) to 120 (the highest/worst).[9]

2.4. Surgical technique

2.4.1. Fixation of the stereotactic frame

In the operating room, the Leksell G frame is secured to the patient's head. Four properly sized screws are used to attach the stereotactic frame to the patient's head (Fig. 1).

2.5. Imaging for target localization

The stereotactic frame is not required to obtain an MRI brainlab protocol, which can be done the

Fig. 1. Leksell stereotactic frame attachment to patient's head.

day of operation or even up to a few days beforehand. On the day of the operation, a CT scan is then performed using the frame and the CT fiducial box. From the bottom of the frame to the top of the fiducial set, images are taken at 1–2 mm intervals.

2.6. Target and trajectory

The patient is sent to the operation room after undergoing a CT scan. With the aid of Brainlab software, the CT and MRI series are merged. To ensure that structures on each scan (such as the pineal gland) are overlaid on one another, the fused images are examined and validated (Fig. 2). The X, Y, and Z axes, as well as all rotational axes, are identified when the alignment is complete and the image fusion program volumetrically correlates the MRI image set to the stereotactic CT.

The target is chosen, and anatomic verification is performed using the Brainlab atlas registered together with patient anatomy by the AC and PC points as well as a recognisable side landmarks (as an instance, the putaminopallidal boundary of the patient's scan corresponding to the in the atlas).

After selecting the initial points, the photos are transformed to the trajectory view. The approach is then tracked at millimeter intervals to make sure it enters a gyrus's crown rather than a sulcus. The thalamic target was the ventral intermediate nucleus of the thalamus (VIM), whereas the pallidal target was at the postero-ventral medial globus pallidus internus (GPi). (Fig. 3).

2.7. Surgical procedure

Our surgical technique was unilateral RF ablation of GPi, VIM or both using macroelectrode stimulation method for target confirmation.

The stereotactic frame is fastened to a Mayfield head holder, and the patient is placed on the examination table in a semi-seated posture. The most affected side is kept uncovered to be able to observe and examine the patient. The entrance point lies 2.5–4 cm from the sagittal suture. A precoronal entry site is selected and a bur hole or twist-drill craniostomy is made in this location to expose the dura mater.

2.8. Target localization

We use a macroelectrode stimulation approach for intraoperative target localization that has been proven to be secure, adequate, and efficient. Stereotactic surgery is made relatively safe by electrical stimulation, mechanical introduction effect observation, and impedance recording.[10,11]

We use a radiofrequency lesion generator Stockert Neuro N50 for macrostimulation and lesion production. 12 mm above the target, a radiofrequency electrode is introduced into the brain. The Impedance is monitored, and the patient is carefully examined during the electrode introduction.

2.9. Macrostimulation in the postero-ventral pallidum

Low-frequency stimulation was employed to gather motor thresholds so as to guarantee that the

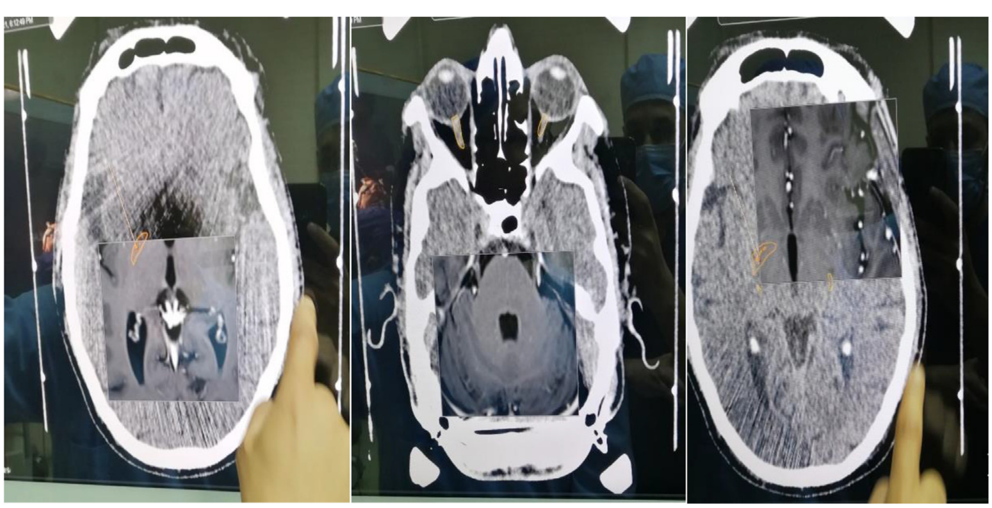

Fig. 2. Checking that the fused CT and MRI images overlie each other.

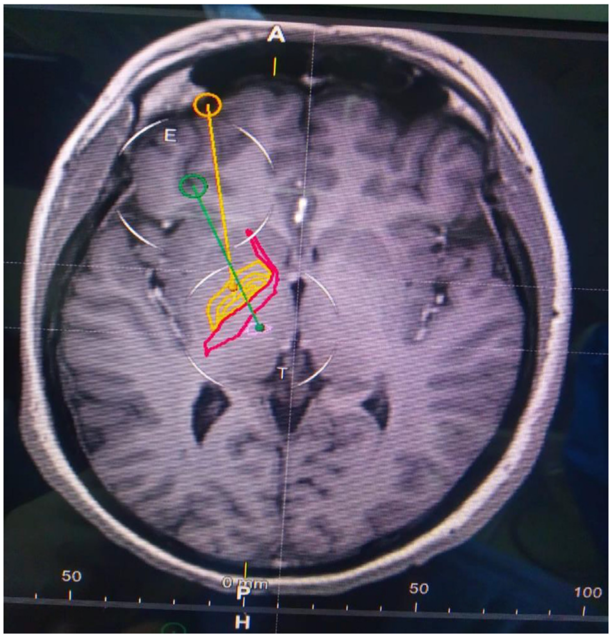

Fig. 3. The surgical goals were the postero-ventral globus pallidus internus and the ventral intermediate nucleus of the thalamus.

lesion site was not affecting the internal capsule. The proximity of the optic tract was measured with high-frequency stimulation. At 6, 4, and 2 mm above the target as well as the target itself, low and high-frequency stimulation were applied. If stimulation has no negative side effects, we begin the coagulation process.

2.10. Macrostimulation in vim

In order to measure the distance to the internal capsule, low-frequency stimulation was first used to collect motor thresholds by carefully monitoring evoked motor activity. An ideal electrode position is associated with paresthesias in the opposing corner of the mouth (labial commissure), the thumb, and the index and middle fingers during the second stimulation session for sensory response.

At the final target, if thalamic high-frequency stimulation results in electrical feeling in the depth of the arm, hand or fingers and tremor arrest, together with concurrent precise, good coordination, fluid, clear speech and strong movements. Then we start ablation.

2.11. Radiofrequency lesion generation

A reversible trial lesion was created at 45 °C for 30 s after the target had been verified in order to evaluate the effectiveness and adverse effects. A permanent lesion was then created after 60 s of heating of 70–80 °C. After that, the electrode was pulled back to 2 mm and 4 mm above the target, and lesioning was done at each location using the same conditions (Fig. 4).

3. Result

Twenty patients underwent thirty-five unilateral RF ablative procedures using intraoperative macrostimulation, 13 males (65 %) and 7 females (35 %) with a mean age (53.75 ± 18.79 year). Seventeen patients were having PD, one patient with post-traumatic Parkinsonism and two with primary generalized dystonia. Patients with severe tremor and rigidity underwent combined VIM thalamotomy and PVP (15 patients, 75 %), while those with Parkinson's disease that is tremor-dominant was

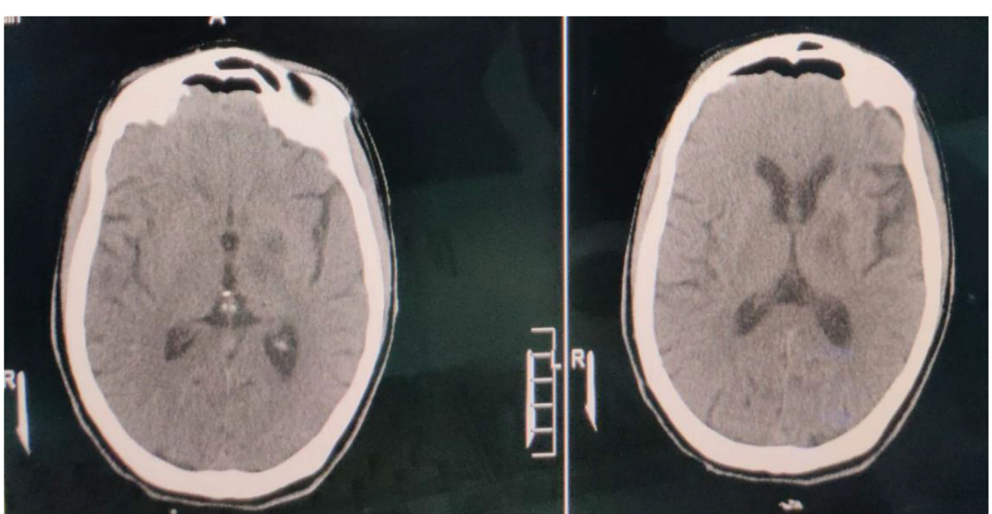

Fig. 4. CT scan of the brain taken right after a combined thalamotomy and pallidotomy.

offered VIM thalamotomy (two patients, 10 %), and those whose primary issue was bradykinesia and rigidity was given PVP (one patient, 5 %). Moreover, PVP was given to those who had primary generalized dystonia (two patients, 10 %).

3.1. Lesioning for Parkinsonism

The total UPDRS–III–off stage dramatically improved from pre-op 46.11 to post-op 14.89 (67.7 % improvement, $P < 0.001$), primarily on the side opposite the surgical site. While the patient was still on the operating table, a significant improvement was noticed in the contralateral rigidity (68.24 %), tremors (84.29 %), and bradykinesia (75.36 %), and it lasted throughout the 6-month follow-up period. Preoperative mean modified Hoehn and Yahr score was 3.83 (range 1–7), and it decreased to 1.22 after surgery (range 0–3). (Table 1).

3.2. Lesioning for generalized dystonia

The total movement score on the BFMDRS decreased from a mean of 46.5 prior to surgery to 29 one month afterwards (P 0.043), which represents a 37.63 % improvement. Moreover, the disability score decreased from 14.25 prior to surgery to 11, representing a 22.8 % improvement (P 0.049).

Both dystonia patients followed for only one month, the child died due to respiratory compromise, while the adult patient who was planned for staged bilateral pallidotomy failed to achieve surgical benefits for long period and missed during the follow-up period.

3.3. Surgery complications

Pneumocephaly was found in 10 patients (50 %), clinically silent minute hemorrhage occurred at the lesion sight in 3 patients (15 %). Both of the side effects were detected in the immediate post-operative CT scan and resolved spontaneously (Fig. 5).

Transient hemiparesis and dysthesia had occurred in tow patients (10 %) which resolved spontaneously after one month, it was attributed to perilesional edema. Two patients suffered from one attack of seizure (10 %), one of them had focal seizure and the other one had focal seizure with secondary generalization resulted in transient impairment of conscious level.

The patient who underwent thalamotomy for posttraumatic Parkinsonism failed to achieve any improvement during the intra op stimulation, instead side effects were more pronounced, so the surgery was aborted for patient safety and to do no harm.

4. Discussion

The deep basal nuclei could now be reached reasonably safely because to the development of stereotactic localization techniques in the late 1940s.[12] Pallidotomy was employed to treat rigidity and bradykinesia, and thalamotomy was used for tremor treatment in the 1950s and 1960s.[13] The introduction of levodopa medication, however, significantly decreased the need for surgery for movement disorders. Long-term L-dopa therapy's drawbacks became apparent, which rekindled interest in surgical treatments.[14] Laitenen revived Leksell's PVP for PD and addressed that the

Table 1. A comparison of pre-op and 6-months post-op UPDRS: III 'Off Meds' among patients of Parkinson's disease.

UPDRS: III 'Off Meds'	Preoperative	6-months Postoperative	Wilcoxon test		
			MD±SEM	z-test	*P* value
Speech	1.56 ± 0.78	0.78 ± 0.55	−0.78 ± 0.10	7.714	<0.001**
Facial expression	1.78 ± 1.06	1.11 ± 0.76	−0.67 ± 0.14	4.761	<0.001**
Tremor at rest	6.78 ± 1.99	1.00 ± 1.41	−5.78 ± 0.49	11.820	<0.001**
Action or postural tremor	4.17 ± 1.58	0.72 ± 0.96	−3.45 ± 0.35	9.981	<0.001**
Rigidity	8.22 ± 3.06	2.61 ± 1.58	−5.61 ± 0.58	9.612	<0.001**
Finger taps	3.83 ± 1.34	1.22 ± 1.11	−2.61 ± 0.32	8.040	<0.001**
Hand movements	3.72 ± 1.41	0.83 ± 0.79	−2.89 ± 0.32	8.965	<0.001**
Rapid alternating movements of hands	3.72 ± 1.32	1.39 ± 1.04	−2.33 ± 0.26	9.127	<0.001**
Leg agility	2.94 ± 1.26	1.06 ± 0.80	−1.88 ± 0.23	8.318	<0.001**
Arising from chair	2.11 ± 1.23	0.83 ± 0.71	−1.28 ± 0.16	8.102	<0.001**
Posture	1.56 ± 0.86	1.11 ± 0.76	−0.45 ± 0.12	3.688	0.002*
Gait	1.89 ± 0.96	1.00 ± 0.77	−0.89 ± 0.16	5.575	<0.001**
Postural stability	1.39 ± 0.85	0.56 ± 0.62	−0.83 ± 0.15	5.718	<0.001**
Bradykinesia	2.72 ± 0.96	0.67 ± 0.59	−2.05 ± 0.21	9.994	<0.001**
Total	46.11 ± 12.73	14.89 ± 6.82	−31.22 ± 2.44	12.812	<0.001**

**P* value < 0.05 S.
***P* value < 0.001 HS.

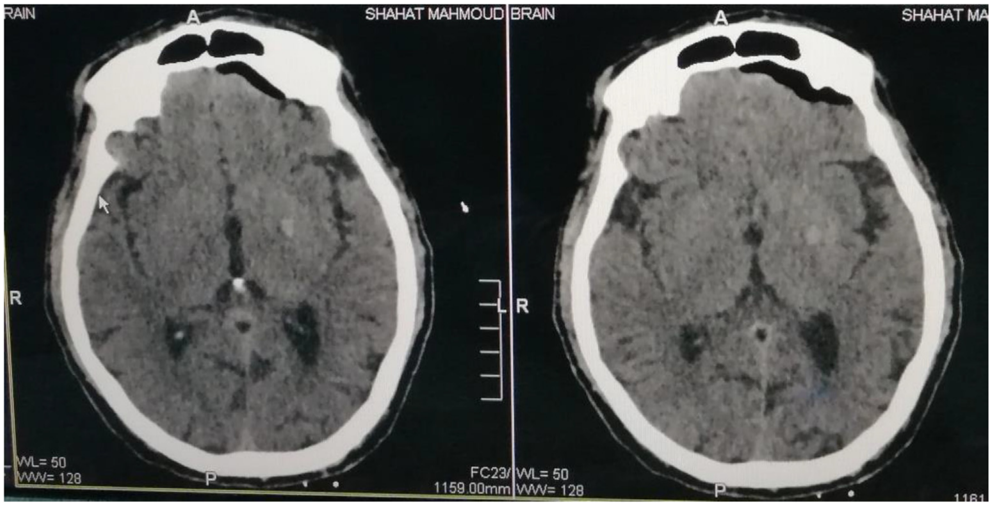

Fig. 5. Post-op CT brain showing pneumocephaly and minute hemorrhage occurred at the lesion sight.

posterior aspects of the pallidum are more crucial for the regulation of motor function than the anterior aspects.[15]

Stereotactic thalamotomy provides a good relief of intractable tremor in PD patients. However, bradykinesia and rigidity are often less responsive and, despite the fact that PVP can reduce rigidity, appendicular bradykinesia, and dyskinesias, tremor may still persist. So, Iacono et al. coupled PVP with Vim thalamotomy in individuals who had severe bradykinesia, rigidity and tremor. The majority of symptoms in patients with tremor-dominant PD are effectively relieved by the synergistic therapeutic benefits of PVP and Vim thalamotomy.[16]

4.1. Lesioning for Parkinsonism

Our findings agree with the findings of other teams. All of the cardinal motor symptoms of Parkinson's disease (PD) significantly improved, primarily on the side opposite the lesion. These advantages persisted over the course of the follow-up period of six months.

The surgical failure in posttraumatic Parkinsonism may be due to development of aberrant communication and maladaptive reorganization within the basal ganglia networks.[17]

Levodopa is beneficial as a symptomatic complement to unilateral pallidotomy and thalamotomy for motor fluctuations and dyskinesia, corresponding to the Movement Disorder Society's most recent evidence-based medicine review.[18]

4.2. Pallidotomy

There have been two prospective single-blind randomised trials that compare unilateral pallidotomy with the best available medical care. In de Bie et al., 1999, patients were randomised to receive either best medical care or a unilateral pallidotomy. Subjects underwent pallidotomy guided by macroelectrode stimulation and were monitored after six months. In contrast to the control participants, who had a mean baseline UPDRS motor score of 52.5 and deteriorated to 56.6 worsened by 7.6 %, the pallidotomy group's mean UPDRS motor score improved (31 %) from a mean baseline of 47.0 to 32.5. In contrast, individuals receiving only medical therapy saw a 5 % worsening in their ‘off’ motor UPDRS motor score at 6 months in the Vitek et al., 2003 study. At two years, the reduction in midline symptoms, such as postural stability, gait, and freezing, had gradually restored to baseline. Nonetheless, 40 % of the patients continued to show a noticeable improvement in gait during this time.[19,20]

After Laitinen et al., several carefully planned experiments of PVP[21–27] were conducted. The off-state UPDRS motor subscale score showed improvement between 14 and 70 % throughout follow-up intervals of 3 months to 1 year.

4.3. Thalamotomy

The Mayo Clinic successfully conducted one of the first significant post-L-dopa stereotactic thalamotomy series for Parkinson's tremor. Thirty-one (86 %) of the 36 individuals in this study who had thalamotomy treatment had their tremor completely eliminated. Three more (5 %) saw a noticeable improvement. Throughout the 14–68 month follow-up period, only two patients experienced recurrent tremor within 3 months of surgery.[28]

When Jankovic et al. looked back at the results of stereotactic Vim thalamotomy in patients with parkinsonian tremor and posttraumatic tremor, they found that 86 % and 50 % of the cases, respectively, improved.[29]

4.4. Lesioning for generalized dystonia

In our study in spite of the initial encouraging results; both patients were missed after one month and we didn't try PVP for other GD patients due to the availability of DBS which is safer to be done bilaterally.

Excellent outcomes with a BFMDRS score improvement of 50%−90 have been reported in prior research on bilateral pallidotomy for dystonia.[30−34] Retrospective analysis of primary dystonia patients who underwent pallidotomies between 2014 and 2019 was conducted by Horisawa et al. in 2021. The overall BFMDRS score was significantly improved by 51.8 % following unilateral pallidotomy. The total BFMDRS score was dramatically improved by 74.0 % following bilateral pallidotomy. Bilateral pallidotomy, however, resulted in five individuals developing medically resistant Parkinsonism, three patients developed dysarthria, and one patient developed dysphagia. They came to the conclusion that unilateral radiofrequency pallidotomy is still an effective treatment for some types of dystonia. However, due to unacceptable high complication rates, bilateral pallidotomy is better to be avoided.[34]

4.5. Electrophysiologic localization

We consider macrostimulation a simple, non-sophisticated method for safe target localization. It is a cost-effective, requiring less instruments and shortens the duration of surgery when compared to microelectrode recording (MER) techniques.

MER allows recognition of the unique neuronal firing patterns in the basal nuclei. Many microelectrodes are extremely sharp (diameters range from 1 to 4 μm) and frequently pass through the target numerous times to map it, increasing the amount of time needed during the procedure as well as the cost and complexity of the method.[35]

The diameter of macroelectrodes is 1−2 mm, and they are more blunt, allowing for the measuring of tissue impedance. The uninsulated tip can be used to provide brief current pulses to examine a patient's response to stimulation (macrostimulation), and high-frequency stimulation can simulate a lesion before it is created.[36]

In a meta-analysis of articles published between 1992 and 2000 on the utility of unilateral pallidotomy in PD. A higher intracranial hemorrhage rate was found in MER group (1.3 ± 0.4 %) when compared with macroelectrode stimulation group (0.25 ± 0.2 %).[35]

4.6. Complications

With careful patient selection, exact targeting, and the application of macrostimulation prior to lesion making, the majority of problems from pallidotomy and thalamotomy can be avoided. All treatments have a learning curve, and difficulties get easier the more experience you have.

The complications we experienced in our series were minimal and accepted, and there were no permanent side effects.

The increased risk of complications after lesion surgery is one of the worries. In the Doshi et al. (2021) series, the rates of overall complications and persistent complications were 14 % and 4 %, respectively.[37]

Intracerebral hemorrhage is one of the most dangerous side effects of pallidotomy. The incidence ranged from 0 to 15 % in a meta-analysis of 19 publications published between 1992 and 1998, with a mean of about 2 %. The overall frequency of pallidotomy-related deaths was 0.3 %.[38] De Bie and colleagues (2002) conducted a thorough analysis of the morbidity and mortality related to unilateral pallidotomy and discovered a risk of relentless adverse events of 13.8 %, symptomatic infarction or hemorrhage of 3.9 %, and mortality of 1.2 %.[39]

In a group of 1116 individuals, Hua et al. (2003) reported that 4 patients (0.4 %) had abnormalities in their visual fields that were irreversible. 47 patients (4.2 %) had weakness, including 13 with acute weakness and 34 with delayed weakness. Seizures occurred in two patients. One day after surgery, two patients went into coma for unknown causes. 24 patients had temporary mental disorientation that began the day after surgery and went away entirely one or two days later.[40]

Due to reports of dysarthria, substantial hypophonia and deteriorating neuropsychiatric and cognitive function after bilateral pallidotomies, pallidotomy has mostly been limited to unilateral surgeries.[39] After bilateral pallidotomy, there was a high incidence of unexpected gait disturbance and postural instability that was resistant to levodopa. DBS should be used while doing bilateral pallidal intervention to prevent severe, permanent Parkinsonism.[34]

Dysarthria, paresthesia, gait ataxia, dystonia, limb weakness, sensory loss, speech difficulties, and cognitive decline are some of the adverse effects of thalamotomy. Bilateral lesions are more likely to cause dysarthria, ataxia, and cognitive impairment, with a frequency of up to 50 % in certain series. 1 % of people experience seizures. Less than 2 % of cases result in hemorrhagic complications. The overall complication rate is predicted to be between 15 % and 20 %, with a permanent impairment incidence of about 5 %. When high-risk individuals are involved or bilateral lesions are done, these rates can increase by a factor of two or three.[41,42] Paresthesia, numbness, and other sensory complaints are frequently reported but normally go away. They commonly affect the perioral region or the appendices.[43]

4.7. Conclusion

Ablative techniques based on macrostimulation continue to be a surgical possibility for PD patients, even in the age of stimulation and MER. Unilateral pallidotomy and thalamotomy can serve as a safe, cost-efficient, and effective treatment for selected patients with PD. Since there appear to be no additional hazards, patients with severe tremor, stiffness, and bradykynesia who have tried pharmaceutical therapy may benefit from the combination of unilateral Vim thalamotomy and PVP.

Authorship

The author has a substantial contribution to the article.

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Disclosure

The author has no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the author.

Conflicts of interest

The authors declare no conflict of interest.

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