Ablative Procedures without Microelectrode Recording in the Management of Advanced Parkinson’s Disease: Complications, Safety and Outcome

Zeiad Y. Fayed* and Aliaa Mansour

Neurosurgery Department, Ain Shams University
Neurology Department Ain Shams University

ABSTRACT

**Background.** Lesion therapy has been used for Parkinson’s disease (PD) and other movement disorders since the early 1900s. More recently, better understanding of the pathophysiological basis underlying the development of PD in addition to the advances in imaging technology and electrophysiological techniques used for localization of brain structures have improved the ability to accurately identify and lesion different targets deep within the brain. **Objectives.** The use of microelectrode recording for determining the optimal lesion location has been a subject of debate. The aim of the study is to assess the complications, safety and efficacy of the different ablative procedures without the use of microelectrode recording in the treatment of advanced Parkinson’s disease. **Methods:** Eighty three patients diagnosed with advanced Parkinson’s disease received ablative procedures, namely: thalamotomy and pallidotomy. Intraoperative microstimulation was used to optimize lesion placement and to avoid injury to nearby structures. The patients were evaluated preoperatively and 1 month, 6 and 18 months post-operatively both clinically and using the Unified Parkinson’s Disease Rating Scale (UPDRS). **Results:** One hundred and five ablative procedures:-thalamotomy and pallidotomy were done without using microelectrode recording for the eighty three patients with advanced Parkinson’s disease. After pallidotomy, 36% improvement in the UPDRS off motor scores and 40% improvements in the UPDRS activities of daily living (ADL) off scores were observed, improvement after thalamotomy in the off motor and the ADL off scores were 16%, 33 % respectively, improvement was also noted in the UPDRS on motor and ADL scores, total “on” time, levodopa-induced dyskinesias, and contralateral tremor. These improvements were maintained at 18 months postoperatively. The overall incidence of complications was thus 13.4%, permanent complications being 5.8% the rest were transient with total resolution within few weeks postoperatively, hemorrhagic complications of in this series was 4.8%, visual field defects occurred in 10 % of pallidotomy patients. **Conclusion:** The Ablative procedures, namely thalamotomy and pallidotomy without using microelectrode recording for the Parkinson’s disease are relatively safe and effective, with only minimal and/or transient complications.

INTRODUCTION

Neurosurgical intervention in advanced idiopathic Parkinson’s disease (PD) has proliferated in the past decades with the failure of medical therapy to maintain quality of life and to effectively keep long term control of different motor symptoms of Parkinson’s disease1. Lesion therapy has been used for Parkinson’s disease (PD) since the early 1900s. During this time lesions have been placed throughout the neaxis with different approaches and varying degrees of success. They have often been employed with little rationale. Today, however, advances in our understanding of the pathophysiological basis underlying the development of PD and other movement disorders has led to a better understanding of why lesioning certain portions of the nervous system should improve motor function. Advances in technology in the areas of imaging and in techniques used for localization of brain structures, such as microelectrode mapping, have improved the ability of physicians to accurately identify and lesion target structures deep within the brain. This improvement has led to an increase in the degree and consistency of clinical benefit2, however with the development of deep brain stimulation techniques, the role of lesion therapy in the treatment of patients with movement disorders has been questioned.

Despite the wide acceptance of ablative procedures, especially when deep brain stimulation (DBS) is not feasible, several issues remain poorly defined and are the subject of much debate, amongst these is the necessity of obtaining microelectrode recordings and whether the use of microelectrode recording enhances the efficacy or safety of pallidotomy and thalamotomy or whether it increases the risk of perioperative complications3.

*Corresponding Author:
Zeiad Y. Fayed
Neurosurgery Department, Ain Shams University
Email: Zeiadfayed@med.asu.edu.eg; Tel.: 01115142226
In this paper we describe and compare the clinical outcome of the two most widely used ablative procedures postero-ventral pallidotomy (PVP) and ventro intermediate nucleus (VIM) thalamotomy performed using macrostimulation guidance and present the complications of both procedures.

**PATIENTS AND METHODS**

During the period from August 2005 to December 2014, eighty three patients with PD were selected to undergo surgery at Ain Shams university hospitals in order to control their motor symptoms, all the patients met the disabling symptoms despite having received appropriate pharmacotherapy. Patients whose problem was postural instability or on period gait freezing and patients with significant cognitive impairment, psychiatric history (unrelated to medication), severe comorbidity from other medical problems, and no or poor response to L-dopa were deemed ineligible for surgery.

We performed 105 ablative procedures in the eighty three patients, those patients with tremor dominant Parkinson’s disease were offered ventro-intermediate nucleus (VIM) thalamotomy (unilateral or bilateral) while those whose main problem was bradykinesia, rigidity or levodopa induced dyskinesia received postero-ventral pallidotomy (PVP) (unilateral or bilateral). Patients with asymmetrical symptoms were selected for unilateral surgery to improve disability in the more affected limb. If a unilateral procedure was thought unlikely to be of sufficient benefit, for instance, in those with disabling bilateral dyskinesia or tremors, a bilateral thalamotomy or postero-ventral pallidotomy was performed. Patients with combined thalamotomy and pallidotomy were excluded from this study.

Preoperative baseline neurological evaluations were conducted during the on state and the off state according to the Core Assessment Program for Intracerebral Transplanation (CAPIT) Committee definition, the practically defined “off” results from a 12h withdrawal of anti-Parkinsonian medications and the best “on” is defined as that condition that both patient and physician agree represents the maximal therapeutic benefit from medication using the UPDRS. The patients were evaluated in the first postoperative day and they returned for follow up evaluations at 1, 6 and 18 months after surgery, and the same clinical rating scales were applied.

All patients underwent routine preoperative brain magnetic resonance MR imaging so that gross structural abnormalities could be ruled out. Most patients underwent MR or computed axial tomography (CAT) imaging within 24 hours after surgery and/or MR at the 18 months postoperative assessment.

**Imaging and Targeting**

Patients were not given anti-PD medications for 8 to 12 hours before surgery. Medications were withheld to ensure that the patients were in a relatively off state so that involuntary movements could be minimized during imaging and to facilitate assessment of the clinical effects during the surgical procedure. After placement of a stereotactic frame (CRW Stereotactic System; Radionics, Inc., Burlington, MA or Leksell type G frame, Elekta, Stockholm, Sweden), Axial T1-weighted MR images (1-mm slices), proton density or inversion recovery MR images or thin cuts 1-3mm CAT scan images were obtained through the basal ganglia and the thalamus, we used MRI (1.5 Tesla) guidance in seventy one patients and the CAT guidance in twelve patients.

The initial pallidal target was chosen to be 2 to 4 mm in front of the mid-commissural point, 4 to 6 mm below the inter-commissural line, and 18 to 22 mm lateral to the midline of the third ventricle in the postero-ventral medial globus pallidus internus (GPi) while the initial thalamic target was taken 25% of the anterior commissure - posterior commissure (AC-PC) distance in front of the PC 13-15 mm lateral to the midline and at the same horizontal plane as the AC-PC line, adjustments were made depending on the relative size and dimensions of the head, the width of the third ventricle, and the location of the posterior limb of the internal capsule.

**Surgical Technique**

**Electrode insertion**

After target coordinate calculation, a frontal burr hole was placed 1 cm anterior to the coronal suture, 5-6 cm lateral to the midline, so that the electrode trajectory subtended an angle of 65° to 70° relative to the intercommissural plane and 5 to 10 ° lateral to the mid-sagittal plane. Stimulation and lesioning were performed using one of three types of RF generators: Radionics Inc. (Burlington, MA) or InnomedNeuro N50 (Munich, Germany) or Elekta (Stockholm, Sweden). A macro-electrode with a 2 mm exposed tip 1.8–mm in diameter was introduced to the target through a guide tube by using impedance monitoring. Impedance was often seen to drop when the grey matter of the basal ganglia or the thalamus was reached, but this outcome was not always reliable.

**Intraoperative macrostimulation**

Macro-stimulation was used to confirm the optimal target location. Low frequency stimulation (2-msec square-wave pulse, 2 Hz, 0–5 V) was used to obtain motor thresholds to assess the proximity to the internal capsule. High frequency stimulation (2-msec square-wave pulses, 50–75 Hz, 0–5 V) was used to assess proximity to ventro-caudal (VC) thalamic nucleus and to the optic tract, potential for speech dysfunction, and amelioration of symptoms.
A third stimulation frequency was used to suppress tremor (tremor arrest) this was done at 180-200Hz, in case of appropriate electrode placement this stimulation may suppress tremor completely at a current intensity at or below 0.5V.

In 18 procedures of the 105, the initial stereotactic coordinates were accurate and no change was required in electrode location. In eighty seven cases, one or two instances of repositioning (2 mm each in a single direction) were required to obtain satisfactory threshold values.

**Radiofrequency lesion**

Once the target location was verified, a test lesion was made at 45 °C for 10 seconds. If there were no deficits, a permanent lesion was made at 70 to 80°C for 60 seconds. One patient only needed repositioning after appearance of mild contralateral upper limb weakness after placing the temporary lesion. The electrode was then withdrawn to 2 mm and 4 mm above the target, and a lesion was made at each site by using similar parameters (75–85 °C for 60 seconds).

All pallidotomy patients resumed their preoperative anti-PD medication regimen sat the completion of surgery while in thalamotomy patients anti PD medications were not started except in the cases with residual tremors and with the lowest effective dose. A brain MR image was obtained within the first 24 hours to assess lesion site and to identify any clinically silent complications (Fig. 1) Most patients were discharged home a day after surgery.

![Fig. 1 a&b: Early postoperative brain MRI axial T2 24 hours after surgery in a: VIM thalamotomy and b: Postero-ventral pallidotomy](image)

**RESULTS**

**Patients characteristics**

Eighty three patients underwent one hundred and five ablative procedures fifty two females and thirty one males with a mean age 59.3±9.4 and mean disease duration before surgery 6.5±2.1 years. Thalamotomy was done in forty seven patients (56%) bilateral in eighteen patients and unilateral in twenty nine patients with a total of sixty five thalamotomies, while pallidotomy was done in thirty six patients (44%) bilaterally in four patients and unilaterally in thirty patients, two patients underwent redo pallidotomy due do worsening of the symptoms after initial improvement with a total of fourty pallidotomies.

**Overall Clinical Improvement**

A subjective assessment of overall outcome was performed at 6 months postoperativelyrating the clinical outcome as excellent, good, moderate, unchanged, or worse compared with the patient’s preoperative condition by the Patients or relatives. 72 % of pallidotomy patients and 97% of thalamotomy patients reported a good or excellent outcome, 19% of pallidotomy patients and 3% of thalamotomy patients experienced moderate improvement. While in pallidotomy patients 7% had no improvement and 2% experienced a worsening of symptoms following the procedure.

**On-Period Changes**

The number of hours per day that patients were in the on state increased after pallidotomy from 7.9 to 11.3 (41%), this was also noted, though to a lesser extent, after thalamotomy from 13.8 to 15.8 (14%). This change in the on period duration was statistically significant and was maintained at 18 months (p = 0.05).

**Dyskinesia**

Dyskinesias was evaluated using a five- point scale (0 = no dyskinesia, 1 = mild dyskinesia, 2 = constant dyskinesia with no interfere with ADL, 3 = dyskinesia that interferes with ADL, and 4 = incapacitating dyskinesia). After pallidotomy, the severity of contralateral dyskinesias decreased by 79% from an average score of 2.9 to a score of 0.6. This change was significant and was maintained at 18 months (p=0.05). On the other hand, ipsilateral dyskinesias improved by 22%, an improvement which regressed to 5% at 18months. Virtually all patients also reported considerable improvement in the number of hours per day during which dyskinesias were prominent from a mean 4.4 hours to a mean of 1.2 hours of prominent dyskinesia per day. This decrease was maintained and was significant at 18 months after surgery (p =0.05) (Fig. 2)

In contrast, thalamotomy only improved contralateral dyskinesia by 15.4% and ipsilateral dyskinesia did no show any statistically significant improvement.
Fig. 2: Bar graph depicting the change in contralateral and ipsilateral dyskinesia after a: Pallidotomy and b: Thalamotomy. The scores were obtained preoperatively (pre-op) and at 1, 6 and 18 months postoperatively.

**Tremors**

The severity of tremors was also rated using a five-point scale similar to that used for evaluating dyskinesia. The severity of contralateral tremors significantly decreased by 65% after pallidotomy from a mean score of 1.27 to 0.45 (p = 0.05), this improvement was only 40% at 18 months whereas ipsilateral tremors was not significantly changed by pallidotomy.  

In the sixty four thalamotomies performed in forty six tremor dominant patients (twenty four males and twenty two females), sixty one thalamotomies were followed by total abolition of the tremors, at 18 months postoperative, sixty of them were tremor free, one patient had recurrence of the tremors, two patients had subtotal abolition of the tremor and one patient only did not show any improvement.

**UPDRS Assessment**

**Pallidotomy**

The mean UPDRS ADL score during the off periods decreased significantly after pallidotomy by 40% from a preoperative mean of 26±1.6 to a mean of 15.4±2.3 1 month postoperatively and 14.9±1.6 (42% below the preoperative level) at 18 months postoperatively (p = 0.05) while the mean in the on periods improved by 21%, 20%, at 1 month and 18 months respectively.

Total off UPDRS motor scores showed 36% improvement in motor scores from a mean of 56±1.1 to a mean of 35.4±1.8 at 1 month which was maintained at 18 months (Fig. 4). There was no significant change in medication regimens (dopa equivalents).

No significant changes were seen postoperatively in the UPDRS mentation scores in patients after pallidotomy.

**Thalamotomy**

The off ADL score showed a significant improvement postoperatively from a mean of 21±1.9 to a mean of 14±1.4 and a mean of 15±1.4 after 18 months. On-period scores also improved but to a lesser extent, from 12±1.5 to 10±0.8 after 18 months.
Motor scores in off period improved in all the patients by 16% after thalamotomy but this improvement decreased to 12% at 18 months (Fig. 5). Nine patients of the forty six thalamotomy patients were able to stop levodopa following their thalamotomy, while seven patients needed less doses than preoperative, thirty patients were kept on the same preoperative doses.

Lesion site

The lesion site assessment

The final lesion site was decided after satisfactory motor and sensory threshold by macrostimulation patients, this was reached after target modification in 86 procedures (83%) of the procedures 2mm in 62 procedures and 4 mm in 24 procedures, final target modifications was done in 65 % of pallidotomies (26 pallidotomies) (all 2 mm or less), 92% of thalamotomies (60 thalamotomy) 12 cases of them 4 mm the rest 2 mm or less

In pallidotomy patients, the post operative MRI showed that the center of the lesions was 22.4 ± 0.9 mm lateral to the midline and 4.9 ± 0.3 mm anterior to the mid commissural point. The most inferior aspect of the lesions was 5.3± 0.8 mm below the AC–PC plane. The lesion sites were analyzed with respect to the improvement in dyskinesia, tremor, and UPDRS scores postoperatively, little correlation was found between the lesion site along the antero-posterior and infero-superior dimensions and the outcome. On the other hand, the lateral location of the lesion resulted in a greater improvement in contralateral tremor (p =0.05) while more medial placement of the lesion resulted in better tremor improvement (p=0.05).

In thalamotomy patients, the center of the lesion was 5.4 ± 0.3 mm anterior to the PC, 13.2 ± 1.2 mm lateral to midline, and 0.2 ± 0.7 mm below the AC-PC plane. The correlation between the lesion site within the VIM and the outcome was insignificant but lateral lesions led to greater improvement in lower limb tremors.

Complications

Of the eighty three patients who were included in this series, one thalamotomy patient died one week postoperatively due to an intracerebral hematoma along the track of the electrode, the patient was 72 years old diabetic and hypertensive. He was on aspirin 150 mg daily for 20 years which was stopped one week before surgery, the patient did well intraoperatively with uneventful macrostimulation and lesioning procedures and his tremors completely disappeared but few hours later he started to deteriorate.

Apart from that fatal hematoma, three patients, two thalamotomy and one pallidotomy, had clinically silent cortical hemorrhages detected on postoperative imaging. All were less than 1 cm in diameter, one thalamotomy patient with postoperative transient contralateral hemiparesis, had a small hematoma at the target site 6 mm in diameter.

Other complications included; four pallidotomy patients suffered homonymous hemianopsia (10% of pallidotomies) one of them had his field defect starting approximately 72 hours after surgery and was believed to be due to a delayed ischemic event, it was still there at 18 months postoperative while two of the other three patients showed normal field one pallidotomy and three thalamotomy patients showed speech problems postoperatively in the form of nasal intonation and slurred speech, in the bilateral cases this was mild after the first surgery but increased upon doing the other side and was also present at the 18 month assessment. Three patients (one thalamotomy and two pallidotomies) experienced prolonged confusion postoperatively, two of them the were back to baseline in 2 weeks and the third gradually improved over 1 month. Balance problem were noted only after bilateral surgery two of the four bilateral pallidotomy patients and four of the eighteen bilateral thalamotomy, two patients (one thalamotomy and one pallidotomy) had mild contralateral hemiparesis with no haemorrhages detected in the postoperative imaging. Both patients improved but only the pallidotomy patient returned to baseline, two pallidotomy patients and one thalamotomy patients suffered transient upper motor neuron facial weakness that resolved within 2weeks (Table 1)
Table 1: Complications of pallidotomy and thalamotomy

<table>
<thead>
<tr>
<th></th>
<th>Pallidotomy</th>
<th>Thalamotomy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unilateral</td>
<td>Bilateral</td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Visual</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Speech</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Fits</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Alteredconc</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Weakness</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Behavioural</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Hypersalivation</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Balance</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Facial palsy</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The overall incidence of complications was thus 13.4%, permanent complications being 5.8% while the rest, hemorrhagic complications in this series were 4.8%, 0.96% fatal and 0.9% leading to only transient weakness with 2.9% clinically silent.

**DISCUSSION**

Ablative procedures have been recognized as an effective treatment for Parkinson’s disease for decades. Although there are several different targets and techniques, the benefit to dyskinesia, bradykinesia, rigidity and tremors has been consistently reported after postero-ventralpallidotomy\(^1\),\(^5\),\(^6\) VIM thalamotomy also has been successfully used for the treatment of most forms of tremor, rigidity and dyskinesia associated with PD especially tremor dominant forms\(^2\),\(^7\),\(^8\).

In our series patients’ recruitment into either procedures was according to the dominant clinical features, using VIM thalamotomy for tremor dominant PD patients and postero-ventralpallidotomy to patients who complain mainly of rigidity, bradykinesia and/or Levodopa induced dyskinesia. Though some authors claim that a well-placed lesion in the pallidum is equally effective to thalamic lesions in the treatment of parkinsonian tremor, and thus they advocate the use of pallidotomy as the preferred target, even for tremor-predominant patients\(^2\).

This finding was not consistent throughout the literature\(^9\),\(^10\) and also in our experience. In the patients with pallidotomy, though not tremor dominant in our patients, the improvement of tremors was often partial or late while on the contrary almost all thalamotomy patient showed total and complete immediate abolition of the tremors.

Anatomical target localization has been always the initial step for target identification in movement disorder surgery including ablative procedures. However, physiological verification of these targets is a necessary step before the final target can be confirmed. This is crucial because anatomic inaccuracies due to image distortion, brain shift, cerebrospinal fluid loss, and pneumocephalus can lead to final target deviation\(^11\). In 83% of our cases, repositioning of the electrode was required after performing intraoperative macrostimulation in order to obtain satisfactory clinical outcome and avoid complications.

The debate on, whether microelectrode recording (MER) is essential in order to define and map the target structures, is still active.

The proponents of MER techniques have insisted on the necessity of its use claiming that MER is essential for intraoperative target refinement, by defining the borders of different anatomical structures and targets\(^12\), which in turn improves the clinical results with no added surgical complications.

In a series of 132 MER guided consequentive pallidotomies, Alterman and collaegues reported modification of the final target after MER in 98 % of cases with 12% more than 4 mm without an increase in the risk of intracerebral hematoma\(^13\).

A study of the literature however disclosed that these claims are often not valid most large series report that the use of MER increases the technical difficulty, duration, risk and the complications of these procedures while providing little information of practical consequence\(^14\).

In 1959 patients from 85 articles in 40 centers, Alkhani and Lozano found an increased incidence of intracerebral hemorrhage in the centers using MER (2.7%) than those using only macrostimulation (0.5%), in a retrospective study including 1156 pallidotomies.
Higucci and Iocano and reported that microelectrode recording procedures correlated strongly with ICH (intracerebral haemorrhage) and were associated with an approximately fourfold increase in the risk of ICH and also with the incidence of postoperative hemiparesis without ICH \(^{14}\). Hariz in 2002 concluded that non-MER techniques, based on macrostimulation guidance, are at least five times safer \(^{16}\).

In a metaanalysis comparing the results of pallidotomy performed using microelectrode recording or macroelectrode stimulation, Palur et al reported that there were no significant differences between the two methods with respect to improvements in dyskinesias (\(p=0.66\)) or UPDRS motor scores (\(p=0.62\)). Microelectrode recording was associated with a significantly higher intracranial hemorrhage rate (1.3 ± 0.4%), compared with macroelectrode stimulation (0.25 ± 0.2%) \(^{17}\). In a paper published in 2001 a MER tram detailed their experience in pallidotomy, in thirty six procedures eleven were considered non responders five of them had too small or improperly placed lesions despite the extensive use of MER \(^{18}\).

The answer to this debate would require conducting a randomized controlled prospective study of the clinical outcome following surgery with or without MER, preferably a group who have an equal non-prejudiced attitude towards, and equal confidence and experience in, either technique. Since this is difficult to be found, comparative study of the available literature remains the only way to evaluate the advantages and disadvantages of either technique, in terms of targeting accuracy and surgical complications.

We think that macrostimulation beside being easy and quick and requiring minimal instrumentation, can identify a wide range of structures even at distance from the probe and thus gives the surgeon a clue where to move next. Unlike MER where the tip of the electrode has to be very close to the structure before it can be detected. Also The GPi and the VIM are relatively larger nuclei, than for example the STN (subthalamic nucleus), so precision of placement of the lesion can be relatively less yet still offer optimum clinical results with minimal collateral damage. Last but not least; the higher cost of MER equipments with no evidence of added benefit makes its routine use in procedures like pallidotomy and thalamotomy not a feasible option in a developing country like Egypt in which this study was carried out.

In our study we did not use microelectrode recording in any of our patients. In both patients’ groups we had a lesion location at the planned target in all of the patients. This was reached after target modification in eighty six procedures (83%) of the procedures 2mm in seventy four procedures and 4 mm in twelve procedures.

Final target modifications was done in 65 % of pallidotomies and in 92 % of thalamotomies. In the Alterman series of 132 pallidotomies 98 % of times the final target was modified after MER. This might be the cause of the absence of any visual affection in their series on the other hand clinical improvement was equivalent which may be due to the fact that going ventrally will start to affect the optic tract without altering the clinical outcome especially in larger sized lesions. The higher percentage of the target modifications in VIM might be due to the smaller size of the nucleus and its close proximity to the VC (ventrocaudal nucleus) posteriorly.

The clinical improvement after pallidotomy and thalamotomy has been heavily reported in the literature starting the early nineties. Pallidotomy was found to achieve significant improvement in virtually all clinical features of Parkinson’s disease with reduction in the UPDRS off motor scores ranging from 19 to 35 %\(^{5,6,19}\). Our results demonstrate that pallidotomy performed without microelectrode guidance can provide a marked improvement in UPDRS off motor and ADL scores and that these improvements are comparable in magnitude to those reported in previously published studies.

The improvement was most marked in contralateral dyskinesia, this was also reported in a meta analysis of 11 studies, Lang and colleagues found the most dramatic effect appeared regarding dyskinesias. A 77% reduction of dyskinesias on the side opposite to the surgery and ipsilateral dyskinesias decreased by 43% in 84 patients \(^{20}\), the effect of the procedure on tremors has been a matter of debate with some authors claiming that it is equally effective to thalamotomy in producing tremor control \(^{2}\), in our series improvement in tremors after pallidotomy group was not as effective and rapid as in the thalamotomy group (there was a total relief in the contralateral tremor in almost all the patients) This cannot be explained only by selection bias (selecting patients with high tremor scores for thalamotomy), reduction in the UPDRS scores was more marked in the pallidotomy group than the thalamotomy group which might also be due to the higher mean preoperative off motor scores in this group than the thalamotomy group.

Complications in Parkinson’s disease surgery, despite their relatively low incidence, still remain a significant problem for these procedures which are rarely life saving and are mainly aimed at improving quality of life in patients with this progressive neurological illness.

Haemorrhagic complications has always been the most common in these procedures, clinically silent in the most, with minimal or temporary clinical consequences or, at rare occasions, it can carry a significant morbidity or even mortality \(^{21}\).

In our series we found an overall incidence of haemorrhage of 4.8% with 2.9%. These were clinically silent. In a large meta analysis published in 2012 by Zrinzo et al. they reported an overall incidence of hemorrhage of 5.0%, asymptomatic in 1.9% of cases, symptomatic in 2.1% and resulted in permanent deficit or death in 1.1% \(^{21}\).
The incidence of hematoma in the thalamotomy group (6% for thalamotomies) was lower compared to pallidotomy (2.5% for pallidotomies). This rate of hemorrhagic complications compares favorably with the findings of other studies, and is certainly less than that obtained with microelectrode-guided localization. There was a higher risk of hemorrhage when the VIM was targeted than when GPi was targeted, which was also reported by several other authors. Xiaowu et al., Ben Haim et al., Gorgulho et al., and Hariz et al. in a systematic review concluded that mortality is higher when microelectrodes were used.

The correlation between hemorrhagic complications and the presence or history of chronic hypertension was significant in our series in both pallidotomy and thalamotomy. The mortality rate was found to be 1.2% in a systematic review including 12 prospective studies with 334 pallidotomy patients. The most common causes of intracerebral hematoma along the trajectory or, less frequently, at the target site, are intracerebral hematoma and is certainly less than that obtained with microelectrode-guided localization. There was a higher risk of hemorrhage when the VIM was targeted than when GPi was targeted, which was also reported by several other authors. Xiaowu et al., Ben Haim et al., Gorgulho et al., and Hariz et al. in a systematic review concluded that mortality is higher when microelectrodes were used.

Mortality in movement disorder surgery has been frequently reported. The mortality rate was found to be 1.2% in a systematic review including 12 prospective studies with 334 pallidotomy patients. The most common causes of which are intracerebral hematoma along the trajectory or, less, at the target site, other causes include pulmonary embolism, aspiration pneumonia, and is certainly less than that obtained with microelectrode-guided localization. There was a higher risk of hemorrhage when the VIM was targeted than when GPi was targeted, which was also reported by several other authors. Xiaowu et al., Ben Haim et al., Gorgulho et al., and Hariz et al. in a systematic review concluded that mortality is higher when microelectrodes were used.

We had transient facial weakness in 5.5% of pallidotomy patients and 2% of thalamotomy patients. Transient facial paresis has been reported in 1 to 10% of patients after pallidotomy. The optic tract affection is not uncommon in pallidotomy procedures. Eskinanadar et al. found that MER reduces the risk for optic tract injury when they reviewed 23 pallidotomy studies. The average incidence of optic tract complications was 1.8%, whereas in nine studies in which only macrostimulation was used, the average incidence was 3.1%. Higucci and Lucano also didn’t find any optic tract injury in any of their patients. They had a higher incidence of optic tract affection 10% despite that none of the patients reported any optic response during macrostimulation. We may have to adopt different anesthetic protocols could this be due to the patients being not fully cooperative to report visual phosphonies which need more alertness than motor or sensory threshold.

Bilateral PVP is usually indicated in young-onset PD patients with bilateral dyskinesias during all “on” periods in patients with dystonia dyskinesia and sometimes tremor. Several authors report that simultaneous bilateral PVP is more effective than unilateral pallidotomy with regard to tremor, rigidity, and dyskinesias, without having a significant association with speech and swallowing disturbances, compared with unilateral PVP. Siegel and colleagues also reported significant improvement in walking speed after bilateral PVP.

However, simultaneous bilateral PVP has conferred a high risk of postoperative speech disturbance and reduced verbal fluency in other studies. In our series, we had less bilateral cases to find significance in reporting complications of bilateral surgery. However, while none of the unilateral cases had any speech or balance problems, one of the four bilateral patients had speech difficulty and two had postoperative balance problems. In bilateral thalamotomy, on the other hand, the incidence of speech and balance problems was significantly higher in bilateral patients compared to unilateral.

**CONCLUSION**

In selected patients with PD pallidotomy and thalamotomy can achieve useful functional improvement, abolishing contralateral tremors and levodopa-induced dyskinesias while significantly improving the off period activity of daily living and motor functions. Using techniques that rely mainly on macrostimulation for target confirmation can result in lesions that are both accurate and consistent in the posteroventral GPi and the VIM with a favorable clinical outcome that compare to the results of studies in which microelectrode recording techniques were used. Parkinson’s disease patients have highly variable clinical pictures with a wide diversity in the magnitude and the pathogenesis of functional impairment selecting the target should be done carefully to encompass the patients clinical profile and meet his expectation and achieve satisfactory functional improvement. Both procedures are relatively safe with some difference in the complication profile between both, factors contributing to this difference might include the varied anatomical characteristics of the primary targets of these procedures, thus ablative procedures depending on macrostimulation only should still be a surgical option for patients with Parkinson’s disease even in the era of stimulation and MER, conducting a randomized controlled prospective studies of the clinical outcome is a must in order to adopt or abandon one surgical procedure or technique or another.

**Disclosure:**

The authors have no personal, financial or institutional interest in any of the drugs, materials, or devices described in this article.
REFERENCES

9. Laitinen LV, Bergenheim AT, Hariz MI. Ventroposterolateral pallidotomy can abolish all parkinsonian symptoms. Stereotact Funct Neurosurg 58:14-21,1992
17. Palur RS, Berk C, Schulzer M, Honey CR. A metanalysis comparing the results of pallidotomy performed using microelectrode recording or macroelectrode stimulation. J Neurosurg 96:1058-1062, 2002
28. Iacono RP, Lonser RR, Kuniyoshi S. Unilateral versus bilateral simultaneous posteroven- 
tral pallidotomy in subgroups of patients with Parkinson's disease. Stereotact Funct Neurosurg 65: 6-9, 1995

29. Siegel KL, Metman LV. Effects of bilateral posteroven- 