Deep Brain Stimulation for Parkinson's Disease

Third Edition
DEEP BRAIN STIMULATION for Parkinson’s

Surgery for Parkinson’s disease (PD) has come a long way since it was first developed more than 50 years ago. The newest version of this surgery — deep brain stimulation, or DBS — was developed in the 1990s and is now a standard treatment. Although it is certainly the most important therapeutic advance since the development of levodopa, DBS is not for every person with PD. It is most effective — sometimes, dramatically so — for individuals who experience disabling tremors, wearing-off spells and medication-induced dyskinesia.

It is very important that a person with PD who is thinking of surgery be well informed about the procedures and realistic in his or her expectations. We hope that this booklet will answer some of the questions that people with PD and their families may have. This publication is an update of the earlier Surgery for Parkinson’s Disease, written by Dr. Blair Ford and published by the Parkinson’s Disease Foundation (PDF) in 2002, and re-issued in 2005. The field of DBS continues to advance at a rapid pace, and it is important for the Parkinson’s community to keep up to date.

A feature of this booklet is that you do not have to start at the beginning and read it all the way through. You can choose the subjects that interest you most and read them in the order that suits you best.

By Blair Ford, M.D.
Associate Professor, Department of Neurology
Columbia University Medical Center
Scientific Editor for the Parkinson’s Disease Foundation
TABLE of Contents

1 Introduction 3
2 Historical Perspective 5
3 How Does Deep Brain Stimulation Work? 7
4 Approaches to Deep Brain Stimulation 9
   • VIM thalamic stimulation 9
   • Subthalamic nucleus (STN) stimulation 10
   • Globus pallidus (GPi) stimulation 11
5 The Key Issues: 15
   • Who should consider surgery, and who should not? 15
   • Results of DBS surgery 17
   • Nonmotor fluctuations 17
   • The decision to have surgery 18
   • Long-term results 19
   • Effects of deep brain stimulation on thinking and mood 19
6 Surgery — The Process 21
   • Preparing for surgery 21
   • The brain operation in stages 21
   • The day of surgery 22
   • After the operation 25
   • Placing the battery 25
   • Medications after DBS surgery 26
7 Programming the Stimulator 27
8 Risks of Deep Brain Stimulation 29
   • Risks of surgery 29
   • Adverse effects of stimulation 29
9 Future Perspectives on Surgery for PD 33
10 Ten Commonly-Asked Questions 35

<table>
<thead>
<tr>
<th>If you are interested in this question</th>
<th>Please turn to page:</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does DBS work?</td>
<td>Chapter 3 7</td>
</tr>
<tr>
<td>Who is a good candidate for surgery?</td>
<td>Chapter 5 15</td>
</tr>
<tr>
<td>What is the surgical process?</td>
<td>Chapter 6 21</td>
</tr>
<tr>
<td>What are the potential risks of surgery?</td>
<td>Chapter 8 29</td>
</tr>
<tr>
<td>Commonly-asked questions about surgery</td>
<td>Chapter 10 35</td>
</tr>
</tbody>
</table>
INTRODUCTION

Surgery for Parkinson’s disease (PD) was developed decades before the advent of any of the effective medications that we use today. For most of the past century, innovative surgeons worked to refine surgical treatments for PD. Without the aid of modern neuroimaging, surgeons located many of the brain targets now used for DBS. During the 1940s and 1950s, these procedures consisted of surgically-created lesions in deep parts of the brain to control symptoms of tremor and rigidity. In one frequently-performed procedure, the pallidotomy, a surgeon created a tiny lesion in an area of the brain known as the globus pallidus. When levodopa was introduced as a treatment for PD in the late 1960s, interest in surgical approaches waned dramatically. For the next 30 years, medications dominated the treatment of PD.

Unfortunately, clinical experience has since shown that medical therapy for PD has significant shortcomings. After several years of taking medications, including levodopa (the current “gold standard” of antiparkinsonian agents), many people with PD experience a shortening of benefit following each oral dose, a problem called “wearing-off.” Many of them also develop drug-induced, involuntary writhing and twisting movements, known as dyskinesias. Some people with PD have tremors that simply do not respond to medications. Others experience intolerable side effects of their medications. It was these limitations of medical therapy that re-awakened a strong interest in developing effective, surgically-based techniques for the treatment of PD.

The new techniques of deep brain stimulation are the products of several advances: improved understanding of brain electrical circuitry, developments in brain imaging techniques, improvements in neurosurgery and innovations in medical technology. DBS is the state-of-the-art surgical treatment for Parkinson’s disease, and has replaced all earlier types of surgery, including pallidotomy. Over 10 years of experience with tens of thousands of patients has established DBS as a safe and effective treatment for the symptoms of PD. The goal of this booklet is to describe DBS and to address some of the issues that people with PD and their families should consider.
HISTORICAL Perspective

It may not make obvious sense that shutting down brain cells using an electrode will help symptoms of Parkinson's disease. It is even more surprising that scientists discovered the basis for this approach before they understood how the brain controls body movement. As with many important discoveries, surgery for PD began by trial and error, not according to a predetermined theory.

The basis for surgery in the treatment of Parkinson's disease began in the early 1900s, when researchers first performed neurosurgery in animals guided by brain maps. This was known as stereotactic surgery. Neurosurgeons Horsley and Clark developed techniques that allowed them to place lesions — surgically created holes — deep in the brain with great accuracy by injecting tiny amounts of corrosive chemicals. Over the next 40 years, neurosurgeons applied lesion-making techniques to the human brain but no surgeon was able to relieve parkinsonism without injury to the motor system, resulting in weakness.

In the 1940s, Dr. Russell Meyers was the first to perform surgery in the basal ganglia, a deep brain region that is responsible for controlling movement. He found that he could reduce the tremor and rigidity of PD in almost half his patients without causing weakness or other motor deficits. This crucial observation led to the development of all modern neurosurgery for PD, including DBS.

In subsequent decades, surgeons perfected the techniques of placing lesions in the brain. Many different brain sites were targeted: the globus pallidus, the thalamus, the subthalamic nucleus and individual fiber tracts connecting different parts of the basal ganglia [see Figure 1, page 7]. Lesions were created using thermal electrodes that heated brain tissue at their tips, enabling the precise destruction of a small volume of brain tissue.
The accuracy of surgical targeting was improved by electrophysiological recording techniques, first developed in the 1960s. Using tiny electrodes inserted deep into the brain, Dr. Hirotaro Narabayashi was able to find cells in the thalamus that fired in synchrony with the tremor of Parkinson’s disease. This site was later confirmed to be the key DBS target for tremor control. The procedures for making lesions in the thalamus and in the globus pallidus, respectively, were given the names of thalamotomy and pallidotomy.

These early approaches were followed by the development of our current state-of-the-art procedure: deep brain stimulation (DBS), pioneered in France in the early 1990s by Dr. Alim-Louis Benabid. While preparing to create a lesion in the thalamus of a patient, Dr. Benabid noticed that he could stop the tremor simply by giving an electrical stimulation to the same area. He speculated that a wire providing continuous electrical stimulation would be an effective treatment for Parkinson’s tremor.

This idea led to the development of the deep brain stimulator, a device that has proven superior to all earlier surgical approaches that were based on creating lesions. Within less than 10 years from its development, deep brain stimulation replaced the thalamotomy and pallidotomy operations, both of which were less effective and carried an increased operative risk.

Deep brain stimulation on one side of the brain was first approved by the United States Food and Drug Administration (FDA) in 1997 for the treatment of tremor. It was approved for implantation on both sides of the brain in 2002 as a treatment for other parkinsonian symptoms — specifically, rigidity, slowness of movement, and dystonia. In the years since then, tens of thousands of patients worldwide have undergone this treatment. Deep brain stimulation continues to evolve and further improvements in this advanced treatment for PD are expected.

**How Does Deep Brain Stimulation Work?**

When an electrical signal is given to the deep brain structures, normal electrical activities of brain cells are shut down. Why does this help PD? The answer relates to the nature and design of the human motor system. Normal muscle tone, speed of movement, timing and coordination all depend upon a complex flow of signals in electrical pathways of the brain. The parts of the motor system are arranged in connected loops that maintain continuous cycles of electrical activity. An electrical signal that begins in one part of the loop returns to its starting point, establishing a feedback mechanism that prevents excessive activity from developing.

In people with PD, the electrical feedback loops of the deep brain structures function abnormally. Some parts have excessive activity while other parts are underactive: the system is out of balance. Normal movement is replaced by unwanted tremor, rigidity and slowness. By using a deep brain electrode that provides an electrical current, it is possible to jam abnormal signaling between brain structures. This does not remove PD from the brain but it shifts the electrical activity of the system towards the normal state and thereby reduces the main motor symptoms of PD.

Unlike the earlier pallidotomy, which created a permanent lesion in the brain, DBS produces electrical effects that are largely and immediately reversible, and can be controlled by programming. DBS can be delivered to several sites including the thalamus, the globus pallidus and the subthalamic nucleus. DBS on one side of the brain generally reduces symptoms of PD only on the opposite side of the body. For people with symptoms on both sides of their body, DBS must be done on both sides of the brain.
APPRAOCHES to Deep Brain Stimulation

Deep brain stimulation can be delivered to any desired brain structure. In PD, three targets have consistently shown the most important anti-parkinsonian effects: the ventral intermediate (VIM) thalamus, the subthalamic nucleus (STN) and the globus pallidus (GPi) [see Figure 1, page 7]. These brain structures were the targets of earlier procedures: the thalamus was the site of the thalamotomy and the globus pallidus, the site of the pallidotomy. But procedures that involved creating permanent lesions, despite their effectiveness, were replaced in the late 1990s by deep brain stimulation, which had the advantages of safety, reversibility and adjustability. A summary of the common targets for DBS in PD is described in Table 1 on page 13.

In the following section, specific operations are described in detail.

VIM THALAMIC STIMULATION
Thalamic stimulation is for tremor. The thalamus is a large, round, oblong mass of cells that acts as a relay station for many important functions, including motor control. A region on the undersurface of the thalamus called the ventral intermediate (VIM) nucleus is the critical center for all types of tremors. Electrical stimulation of the VIM thalamus can completely and reliably stop a tremor on the opposite side of the body. Thalamic stimulation on both sides of the brain will reduce tremors on both sides of the body, as well as midline tremors of the jaw, neck and trunk.

Thalamic stimulation will suppress tremor of any cause: Parkinson’s tremor, essential tremor (ET), multiple sclerosis (MS) and dystonic tremors. In people with PD who have both essential tremor and Parkinson’s disease tremor (“ET-PD”), thalamic stimulation may provide control of tremor that is superior to deep
APPROACHES to Deep Brain Stimulation

Deep brain stimulation can be delivered to any desired brain structure. In PD, three targets have consistently shown the most important anti-parkinsonian effects: the ventral intermediate (VIM) thalamus, the subthalamic nucleus (STN) and the globus pallidus (GPI) [see Figure 1, page 7]. These brain structures were the targets of earlier procedures: the thalamus was the site of the thalamotomy and the globus pallidus, the site of the pallidotomy. But procedures that involved creating permanent lesions, despite their effectiveness, were replaced in the late 1990s by deep brain stimulation, which had the advantages of safety, reversibility and adjustability. A summary of the common targets for DBS in PD is described in Table 1 on page 13.

In the following section, specific operations are described in detail.

VIM THALAMIC STIMULATION
Thalamic stimulation is for tremor. The thalamus is a large, round, oblong mass of cells that acts as a relay station for many important functions, including motor control. A region on the undersurface of the thalamus called the ventral intermediate (VIM) nucleus is the critical center for all types of tremors. Electrical stimulation of the VIM thalamus can completely and reliably stop a tremor on the opposite side of the body. Thalamic stimulation on both sides of the brain will reduce tremors on both sides of the body, as well as midline tremors of the jaw, neck and trunk.

Thalamic stimulation will suppress tremor of any cause: Parkinson’s tremor, essential tremor (ET), multiple sclerosis (MS) and dystonic tremors. In people with PD who have both essential tremor and Parkinson’s disease tremor (“ET-PD”), thalamic stimulation may provide control of tremor that is superior to deep
brain stimulation in other targets. Sometimes people with PD that have bilateral thalamic stimulation experience slurred speech or poor balance as an adverse effect, but these symptoms can be reversed through adjustments in stimulator settings.

**SUBTHALAMIC NUCLEUS STIMULATION**

The subthalamic nucleus (STN) is a small lens-shaped structure of about 6 mm in length located right beneath the much larger thalamus. The STN can be identified accurately using mapping techniques and a DBS electrode can be placed right through it — much like a toothpick skewers an olive. Stimulation of the STN influences its connections to the globus pallidus and can have broad anti-parkinsonian effects. It can improve not only tremor, but also slowness, rigidity, dyskinesias, speech, handwriting and dystonia. The anti-tremor effect of STN stimulation is comparable to that of thalamic stimulation.

STN stimulation has been performed in thousands of people with PD at many medical centers around the world and is now considered the most effective surgical intervention for PD. In carefully selected individuals, STN stimulation can reduce parkinsonian symptoms in the unmedicated state by 30 to 60 percent, as measured by standard rating scales. With this degree of improvement, people with PD who suffer from disabling wearing-off periods may experience a significant reduction in the severity and duration of these episodes. In some people with PD, the wearing-off periods can be completely eliminated, enabling them to function independently throughout the day.

Many people with PD find that they require less anti-parkinsonian medication after STN stimulation. Some can stop their medication altogether. As a result of the decreased need for medication, and also because of a direct stimulation effect, there may be a dramatic reduction — or even elimination — of dyskinesias. The beneficial effects of STN stimulation generally parallel those of levodopa, but do not surpass the best result of medication treatment. Its main advantage is improvement in wearing-off spells and dyskinesias.

Most people with advanced PD require STN stimulation on both sides of the brain to control symptoms on both sides of the body. STN stimulation on one side generally helps parkinsonian symptoms only on the opposite body side. For people with PD who have tremor or other symptoms on only one side, one-sided STN stimulation may be considered. Gait problems and dyskinesias generally require STN stimulation on both sides of the brain. STN stimulation can also improve parkinsonian symptoms in people with PD who have undergone previous pallidotomy or thalamotomy surgeries.

More research on outcomes will be needed before we know which people with PD will benefit the most from STN stimulation. Some people with PD who undergo DBS have developed problems with memory and thinking, but those with a good cognitive baseline before surgery are less likely to experience these symptoms.

Parkinson’s disease is a progressive disorder. No medical or surgical therapy to date has been able to prevent the development of late symptoms that do not improve with medication, such as memory problems or lack of balance.

**GLOBUS PALLIDUS STIMULATION**

The globus pallidus, named for its pale appearance, is a dense wedge of nerve tissue that occupies the center of the basal ganglia region. The deepest portion of the globus pallidus, named the posteroverentral medial globus pallidus interna (GPI), is the site of the pallidotomy operation, and represents the main outflow connection from the globus pallidus to the thalamus. The globus pallidus is a larger and more complex structure than the STN, with a complicated internal circuitry. Like STN stimulation, globus pallidus stimulation has broad beneficial anti-parkinsonian effects. Because the globus pallidus
is so large, the entire deep brain electrode resides within it, as contrasted with the STN, a much smaller structure in which the electrode protrudes out both sides.

Globus pallidus stimulation has effectiveness similar to that of STN stimulation. The operation is performed less frequently, due to the surgeon's preference or training. In randomized comparisons between the two techniques, the result of bilateral globus pallidus stimulation is the same as that for STN stimulation, a 30 to 60 percent improvement in parkinsonian symptoms in the unmedicated state. Globus pallidus stimulation can also bring about substantial reductions in parkinsonian dyskinesias and dystonia.

An important advantage of surgery at the STN site is that people with Parkinson's who go through surgery are usually able to reduce their medications by a greater amount than those who undergo stimulation of the globus pallidus. Based on this observation, it has been argued that the reduction in dyskinesias following globus pallidus stimulation is a direct effect of the procedure, whereas with STN stimulation, the dyskinesias are improved mainly as a result of the decreased medication requirement.

**TABLE 1. BRAIN SITES FOR DEEP BRAIN STIMULATION**

<table>
<thead>
<tr>
<th>Deep Brain Structure</th>
<th>Effects and Outcome</th>
</tr>
</thead>
</table>
| **Thalamus**         | • Deep brain electrode in VIM thalamus  
                      | • Effective treatment for tremor on the opposite body side  
                      | • Bilateral thalamic stimulation can be accomplished without significant adverse effects |
| **Subthalamic Nucleus (STN)** | • Deep brain electrode in subthalamic nucleus (STN)  
                              | • Effective treatment for tremor, slowness, rigidity, dystonia and dyskinesia on the opposite body side  
                              | • Bilateral procedures well tolerated  
                              | • Usually allows people with PD to decrease medications |
| **Globus Pallidus (GPI)** | • Deep brain electrode in globus pallidus (GPI)  
                            | • Effective treatment for tremor, slowness, rigidity, dystonia and dyskinesia on the opposite body side  
                            | • Bilateral procedures well tolerated |
THE KEY Issues

WHO SHOULD CONSIDER SURGERY, AND WHO SHOULD NOT?
Surgery is not for everyone.

The best candidate for deep brain stimulation is someone who has had Parkinson's disease for 10 to 20 years, and who experiences wearing-off motor fluctuations, episodes of extreme slowness, stiffness and tremors caused by a failure of medication doses, and dyskinesias, twisting movements that are caused by excessive medication. The effect of DBS tends to parallel the best result of individual doses of medication. However, there are some people with a form of PD that is dominated by severe, medication-resistant tremors and these individuals, too, benefit substantially from DBS.

Perhaps the most important determinant of a successful outcome is ensuring that an individual is a good candidate. People with PD who are younger and whose primary problems are tremor and dyskinesias have better results than do older people with PD who have speech problems, balance impairment, and gait freezing spells.

TABLE 2. PATIENT SELECTION DETERMINES OUTCOME

<table>
<thead>
<tr>
<th>Good Candidate for DBS</th>
<th>Poor Candidate for DBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Typical PD with tremor</td>
<td>• Atypical parkinsonism</td>
</tr>
<tr>
<td>• Good response to individual doses of levodopa</td>
<td>• Poor response to levodopa</td>
</tr>
<tr>
<td>• Dyskinesias</td>
<td>• Memory problems, apathy or confusion</td>
</tr>
<tr>
<td>• Wearing-off spells</td>
<td>• Severe depression or anxiety</td>
</tr>
<tr>
<td>• Good general health</td>
<td>• Severe medical problems</td>
</tr>
<tr>
<td>• Excellent family support</td>
<td>• No social support</td>
</tr>
</tbody>
</table>
Candidates who will most likely benefit from DBS have:
- typical "classical" PD, defined by the presence of tremor at rest, rigidity and slowness
- symptoms that still respond to individual doses of their anti-parkinsonian medications even if the response is brief
- disabling parkinsonian symptoms in the "off" state
- uncontrollable medication-induced movements called dyskinesias
- severe tremors
- a good understanding of the potential benefits and risks of the operative procedures and evaluation, and the ability to give informed consent
- good general health
- a good emotional support network of family and friends

Candidates who will likely not benefit from DBS have:
- atypical or rare forms of parkinsonism, such as progressive supranuclear palsy (PSP), multiple system atrophy (MSA), corticobasal ganglionic degeneration (CBGD) or a known acquired cause of parkinsonism such as stroke or brain trauma
- failure to experience any benefit from anti-parkinsonian medications
- severe memory loss, confusion, hallucinations or apathy (these problems may actually get worse as a result of brain surgery)
- presence of freezing, balance problems and frequent falling
- a severe chronic psychiatric disorder such as psychosis, depression, bipolar disorder, alcoholism or a personality disorder
- inability to understand the potential benefits and risks of the operative procedures or to give informed consent
- significant medical problems that would unacceptably increase the surgical risk, such as cancer or serious heart disease

Note that age is not an essential criterion for surgery. An otherwise healthy older person with PD can safely undergo and benefit from this type of surgery. While advanced age does not preclude surgery, the best results are obtained in younger individuals.

RESULTS OF DBS SURGERY
DBS surgery can reduce tremor, stiffness, slowness, wearing-off spells and dyskinesias. These effects can translate into gains in performing activities of daily living and improved mobility, independence, self-esteem and quality of life. Handwriting may improve, speech may become stronger, and walking is better. Some people with PD who undergo DBS surgery experience a significant improvement in sleep quality. Weight gain after surgery has been noted in many people with PD.

It is important to recognize that some symptoms of Parkinson's disease may not respond better to surgery than others. The effect of surgery on slowness and stiffness can generally be predicted from the response to individual doses of medication.

Some people with Parkinson's disease have an excellent response to levodopa and other medications, with almost complete suppression of symptoms, but suffer from spells of wearing-off during which they become stiff, immobile and frozen. These individuals will benefit from surgery because at least some of the time, their parkinsonism is levodopa-responsive.

Other people with PD have an incomplete response to levodopa. Even when experiencing their maximal medication effect, they have some gait, balance or speech impairment. These people with PD, who do not do as well on regular anti-parkinsonian medications, will also not gain as much relief from surgery. They will probably only experience relief of those symptoms that are eased by their medication. People with PD who cannot walk independently at their best on levodopa will still not be able to walk after surgery.

NONMOTOR FLUCTUATIONS
Some people with PD who experience severe wearing-off spells also suffer from "nonmotor fluctuations," episodes of anxiety, depression, bladder or bowel impairment, or painful sensations that fluctuate in parallel with their parkinsonian episodes of stiffness and slowness. It is unclear whether DBS can relieve these distressing symptoms, and more research is needed to address this important area.
TABLE 3. PREDICTING BENEFIT FROM DEEP BRAIN STIMULATION

<table>
<thead>
<tr>
<th>DBS helps with:</th>
<th>DBS does not help with:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tremor</td>
<td>Freezing</td>
</tr>
<tr>
<td>Rigidity</td>
<td>Backwards falling</td>
</tr>
<tr>
<td>Hand function</td>
<td>Tachypnea; rapid, soft, stuttering speech</td>
</tr>
<tr>
<td>Dyskinesias</td>
<td>Flexed neck or posture</td>
</tr>
<tr>
<td>Wearing-off spells</td>
<td>Dementia or apathy</td>
</tr>
<tr>
<td></td>
<td>Anxiety or depression</td>
</tr>
</tbody>
</table>

THE DECISION TO HAVE SURGERY

When should surgery be considered? Some have argued that surgery should be performed on people with mild PD in order to delay the progression of disease or forestall complications of medication usage.

This notion is not justified because there is no evidence that earlier surgery can slow disease progression or protect brain cells. Current surgical techniques, along with medications, provide benefit only by suppressing the symptoms of PD. There is no evidence that DBS is neuroprotective. The risks and inconveniences of surgery underscore its role as a treatment of last resort, after medication options have been thoroughly tried. Nonetheless, for people with PD who have entered the phase of dyskinesias or wearing-off spells, earlier surgery may improve quality of life more than complicated medication adjustments.

At some centers, people with PD who are considered candidates for deep brain stimulation undergo a simple test that can help predict the result of surgery. The test consists of observing a person with PD after a moderately large dose of dopamine medication. The usual procedure involves a dose of levodopa, and the test is called a “levodopa challenge.” At other centers, the test involves an injection of the dopamine drug apomorphine. In either case, the improvement that follows a dose of levodopa or apomorphine tends to correlate well with the effects of deep brain stimulation.

Each person with PD is unique, and the goals of surgery are different for each individual. With some, the most pressing requirement is tremor control. With others, it is the need to reduce dyskinesias. It is very important that every person with PD contemplating surgery have a clear idea about what can and what cannot be accomplished by using this powerful intervention.

LONG-TERM RESULTS

What happens in the years after DBS surgery? According to clinical researchers at the medical centers with the longest follow-up data, people with advanced PD continue to experience marked benefits for many years after the operation. Tremor, especially, remains well-controlled but rigidity and dyskinesias are also improved and do not return to the levels that they were before the surgery. A person’s ability to perform activities of daily living may gradually decline after the first year following surgery but remains improved even after five years or more, according to long-term studies. Many people with PD can reduce their medications after surgery and this reduction can persist.

In the early months after surgery, people with PD typically return to the medical center for frequent stimulator adjustments. After the initial adjustment period, the stimulator settings tend to remain stable over time, and only limited additional programming is required to keep symptoms under control. Depending on the settings, the system battery, which is implanted in the chest like a pacemaker, will deplete and require replacement in three to five years.

Unfortunately, PD is a progressive condition. DBS does not prevent later complications of the disease, such as poor posture, speech impairment, gait freezing, balance problems, backwards falling or dementia. If these problems develop in a person with PD treated with DBS, the overall gains in quality of life after surgery may be lost, even if tremor and dyskinesias remain well-controlled. A challenge for investigators in the DBS field is to find new targets and approaches for these difficult problems.

EFFECTS OF DEEP BRAIN STIMULATION ON THINKING AND MOOD

Most individuals tolerate brain surgery and deep brain stimulation without noticeable effects in their memory or thinking ability; in some studies, mood, behavior, mental clarity and self-esteem have improved.
There is a small group of patients who experience cognitive decline after surgery. These individuals are typically more elderly and have pre-existing dementia that may include wordfinding difficulty, inability to carry out a sequence of tasks, problems with judging space, and apathy. The presence of dementia at baseline is not an absolute disqualification to DBS if the person with Parkinson’s disease has tremor and other symptoms that would otherwise benefit. However, if the results of pre-operative neuropsychological tests are poor, the appropriateness of DBS may be questioned.

A very small group of individuals has become seriously depressed after surgery and several suicides have been reported. Such individuals invariably had pre-existing depression, a frequent problem in PD that requires careful attention and expert treatment. In most centers, the presence of depression is a disqualifying factor for surgery.

SURGERY — The Process

The prospect of having an operation of any kind is anxiety-provoking. To think of having brain surgery for Parkinson’s disease is enough to tax the emotional resources of even the strongest individual and the most supportive of families.

PREPARING FOR SURGERY

Before surgery, the person with PD and family should educate themselves about the procedure. Deep brain stimulation is an elective procedure and, ultimately, the decision to proceed must be that of the person with PD. He or she should read the available literature and become acquainted with the practical aspects of deep brain stimulation. It can be helpful and reassuring to meet someone who has already gone through the experience. And of course, the person with PD and family must meet the surgeon.

After detailed discussions with the treating neurologist and the surgeon, the patient must undergo pre-operative screening tests. The tests include a brain imaging study, a general medical examination, blood tests, an electrocardiogram, a chest x-ray, neuropsychological testing and any other data collection required by the institution’s protocol. If everything turns out right, and the individual agrees to proceed, the next step is scheduling the surgery.

THE BRAIN OPERATION IN STAGES

DBS involves the placement of an electronic device in stages. Each piece of the apparatus must be fitted into the person with PD and the procedures can be done in any order. A stimulator consists of three parts: (1) DBS lead, or electrode, (2) connecting lead, or wire, and (3) battery [see Figure 4].
1. The DBS lead is an insulated wire with four contacts at its end. The lead is inserted deep into the brain so that its tip directly stimulates the target site. Its other end, near the surface of the brain, is anchored to the inside of the skull.

2. The connecting wire runs under the skin from the DBS lead at the scalp site, behind the ear and down the neck into the chest where it connects to the battery pack, or implantable pulse generator (IPG).

3. The IPG resides like a pacemaker beneath the skin of the chest wall under the collar bone. The IPG is a metal disc about two inches in diameter and one-half inch thick. It contains a small battery and a computer chip. The IPG sends electrical impulses through the connecting wire to the DBS electrode implanted in the brain.

By far the most complicated and time-consuming part of the operation is placement of the DBS lead, which requires careful brain mapping. People with symptoms on both sides of the body require bilateral operations. Sometimes the two DBS leads are implanted in the same operation; at other times, they are staged over two operations that are weeks or months apart. Similarly, some surgeons place the entire apparatus — DBS lead, connector and IPG — in a single, marathon procedure. Others first perform only the DBS lead insertion and delay the rest of the work to a second, outpatient procedure the following week. Some individuals prefer the idea of staged procedures so they can recover between steps, while others “just want to get it over and done.”

THE DAY OF SURGERY
The day of brain surgery may seem endless. Procedures vary from hospital to hospital but the operations generally take three to six hours and are usually performed while individuals are awake, without medication and experiencing PD symptoms at their worst. Thankfully, most people with PD lose track of the passing hours as they lie immobile on the operating table while the surgeons perform their delicate work. Most individuals have no recollection of the surgery.

The first step of the operation is placement of the stereotactic head frame, a large, open casing made of metal bars that is screwed into the patient’s skull at several points. This procedure is done under local anesthesia and is not painful, though some people with PD complain of headache afterwards. Sometimes, the head frame is placed on the person’s head the day before the operation, but it is usually done on the morning of surgery. Some surgeons insert the skull screws days in advance to facilitate attachment of the head frame on the day of the surgery.

The goal of the operation is to place, within millimeter accuracy, an electrode deep inside the brain. The successful outcome and the risks of the procedure depend critically upon accurate targeting. After the head frame is attached, the person with PD undergoes a brain imaging scan while wearing the apparatus. The calibrations on the head frame are merged with the brain image to form a computerized map of the brain. This map becomes the blueprint for planning and measuring the trajectories of the electrodes into the deep brain regions of the basal ganglia. The entire head frame structure is then bolted to the operating table to maintain the head in a fixed position throughout the operation.

The surgeon next creates an operative field by drilling a burr hole (a small opening in the skull made with a surgical drill) into the top of the skull — the passageway for the insertion of the stimulating electrode into the brain. The burr hole is made under local anesthesia, and since the brain is completely anesthetic (has no sensation), the rest of the operation is painless. Because of the need to communicate with the operative team, people with PD undergo surgery while awake. During the procedure, the neurosurgeon asks the person with PD a number of questions about how he or she is feeling and what symptoms he or she may be experiencing. Light anesthesia is sometimes used if the person with PD is uncomfortable.

As an additional means to ensure the accuracy of the surgical probe, some hospital centers perform electrical brain mapping during surgery. This technique uses tiny electrodes that can record electrical activity from individual brain cells within deep brain regions. The
microelectrodes are much smaller and more delicate than the electrodes that provide the deep brain stimulation. They are used to identify cells within the thalamus, globus pallidus, subthalamic nucleus and adjacent brain structures, and help steer the main probe towards the desired surgical target.

**TABLE 4. STEP-BY-STEP PLAN OF OPERATION FOR DBS**

1. Head frame is attached to skull
2. Magnetic resonance imaging is done for brain mapping
3. Burr hole is drilled in scalp under local anesthesia
4. Electrophysiological brain mapping using microelectrode is done
5. Deep brain stimulator electrode is inserted in brain
6. Implantable pulse generator (IPG) is placed in chest wall
7. Connecting wire is attached to IPG in the chest, and tunneled under skin of neck to deep brain electrode at the scalp site

Some surgery centers have begun using a frameless operation for deep brain stimulator implantation. In a frameless setup, the patient’s head is not immobilized in a frame that is bolted to the operating table. Instead, screw mounts are attached to the individual’s skull, sometimes days in advance of the operation. At the time of the operation, a surgical apparatus is fastened to the patient’s head using the screw mounts. The brain mapping and electrode implantation are done using additional devices that can be attached to the skull-mounted apparatus. If the patient’s head moves during the operation, the apparatus moves with it. By permitting the individual’s head to move, the frameless approach improves comfort for a person with PD.

For individuals who have PD symptoms on both sides of their body, electrode insertions need to be performed on both sides of the brain. After the first DBS electrode has been placed, the procedure is repeated on the opposite side. Another burr hole is made, the brain mapping is done all over again and the second-side insertion of the deep brain electrode is accomplished — all within the same operation.

**AFTER THE OPERATION**

The hospitalization required for a deep brain stimulator implantation is usually two or three days. People with PD usually tolerate the procedure very well. Sometimes symptoms are dramatically improved after the DBS electrode is in position, even though the battery has not been attached and the system has not yet been activated. This effect is usually attributed to brain swelling at the tip of the electrode. After the operation, many people with PD find themselves exhausted, and perhaps slightly confused. Some complain of mild headache. These symptoms usually resolve within 24 hours. Most individuals recover quickly and can be safely discharged from the hospital just one or two days after the surgery. Most individuals should remain on their pre-operative medication at discharge, although some centers begin a medication reduction protocol at this point. Typically, people with PD return home with scalp staples or stitches in place, to be removed one week later in the surgeon’s office once the scalp heals.

**PLACING THE BATTERY**

The DBS electrode requires a power source. Once the deep brain electrode has been inserted, the remaining surgical task is implanting the extension wire and the battery, or implantable pulse generator (IPG). This may be done at the same time as the brain implant, or may be deferred to a later date — usually, one week after the brain operation. The operation is relatively simple: the surgeon makes an incision under the collarbone, creates a small pocket in the muscle and inserts the IPG. The IPG is attached to the connecting wire, which is tunneled up the neck, behind the ear and to the scalp site, where the external end of the DBS electrode was implanted previously. The connecting lead is attached to the DBS lead. At this point, the entire apparatus is in place under the skin. The chest wall pocket is closed using stitches or staples. The battery produces a visible bump on the chest, especially in people who are lean.

People with PD treated using electrodes on both sides of the brain have a choice: each electrode can be connected to its own battery, one on each side of the chest, or both electrodes can be connected to a single, larger generator implanted on one side. Both options are acceptable, but there
are practical and cosmetic differences. Having two batteries means two protrusions, one on each side of the chest. Having one battery means a protrusion on only one side — but the battery is larger and more noticeable. In the rare case of a battery failure or infection, individuals with a single battery will lose power in both stimulators. Some people with PD who have cardiac pacemakers and undergo DBS surgery may require placement of the IPG in the abdomen.

The battery implants are performed under general anesthesia. The procedure can be performed during a hospitalization or as an outpatient procedure. When people with PD wake up after the procedure, they may experience chest or neck discomfort and require mild painkillers. Once the batteries and wires are connected, the deep brain stimulation system can be activated. Sometimes, the initial programming is done immediately after the batteries are implanted, but often, this step is postponed until the first post-operative visit. After the batteries are implanted, people with PD are discharged from the hospital, returning to the office the following week to have the stitches or staples removed. After the incisions heal, most individuals report that they do not feel the battery or the wires.

**MEDICATIONS AFTER DBS SURGERY**

Immediately after surgery, most individuals resume their pre-operative medication at their usual doses. However, after the stimulators are turned on and programmed, many people with PD can reduce their medications, a process that must be carefully supervised by the treating neurologist. In some people with PD, eliminating medications that may be causing side effects is an explicit goal of surgery. Drugs that are associated with dyskinesias, such as entacapone or long-acting carbidopa/levodopa, can sometimes be removed. Dopamine agonists that may cause hallucinations, excessive drowsiness or abnormal behaviors can also be reduced. For individuals taking levodopa, an optimal combination of medication and electrical stimulation can usually be determined during the first three months of stimulator adjustments. And for every person with PD, achieving an ideal balance of exercise, nutrition and sleep quality is an important goal of treatment.

**PROGRAMMING the Stimulator**

For people with PD who undergo deep brain stimulation, the surgical operation is just the beginning.

Years ago, the notion of a person with Parkinson’s coming to the office to have deep brain electrodes programmed by a physician or nurse would have seemed like science fiction. Now this scenario happens on a daily basis at busy centers where such procedures are routinely performed.

After the operation, individuals are discharged to home. They must now begin a period of stimulator adjustments, performed over the course of several outpatient visits. The stimulator adjustments and settings are different for every person with PD. Some undergo surgery believing they will be immediately much better after the stimulator devices are activated. In practice, this improvement may take several weeks, even months, while the stimulator settings are being improved and the medications adjusted to an appropriate level.

Physicians and nurses who program the stimulator work with several variables at once: the way the electrode contacts are turned on, the frequency, pulse width and the voltage. In the first months following implantation, people with PD may require frequent adjustments. After this period, the electrical settings usually stabilize.

People with PD may check their deep brain stimulators using a handheld device that resembles a television remote controller. Provided by the stimulator manufacturer, this lightweight plastic handheld device allows people with PD to determine whether their stimulators are in the “on” or “off” position. If the stimulator has inadvertently been
turned off, pressing a button on the remote will turn it back on. The handheld device does not permit individuals to adjust their stimulator parameters themselves or perform any troubleshooting, although future versions will allow this. Any problems with the stimulator require a visit to the medical center to have the device checked.

The life expectancy of the stimulator battery varies with output settings but is estimated at three to five years. As the energy in the battery becomes depleted, the efficacy of the stimulation starts to decline and PD symptoms increase. Individuals can check the battery status using the handheld device or the neurologist can do this in the office. When the battery is depleted, the implantable pulse generator (IPG) will require replacement under light general anesthesia in an ambulatory surgical procedure that takes about one hour. The old IPG is removed from the chest wall site by re-opening the incision. The device is disconnected from the connecting lead, the new IPG is inserted and hooked up, and the incision is again closed with stitches or staples. In the near future, it is expected that externally rechargeable batteries will eliminate the need for battery replacement.

RISKS of Deep Brain Stimulation

RISKS OF SURGERY
Potential complications of surgery for Parkinson's disease range from mild headache or drowsiness to more serious or irreversible effects, such as infection, stroke or hemorrhage. Some people with PD, especially those who are already suffering from mild cognitive problems, may experience post-operative sleepiness, disorientation, slowness of mental processing, hallucinations, poor motivation or depression. These events typically resolve within 24 or 48 hours but may last longer. After bilateral subthalamic nucleus stimulation, some individuals have experienced difficulty opening their eyes. To remedy this, some may need injections of botulinum toxin, a muscle relaxant, around their eyes.

At the medical centers that have the most experience with DBS, the risk of stroke or bleeding is less than five percent per stimulator placement.

Because deep brain stimulation requires implanted hardware, there is a risk of infection, sometimes requiring antibiotics or even replacement of an infected device. Despite every precaution, a skin infection can sometimes occur at the battery site in the chest wall, in the neck or at the scalp. Like all types of surgery, operator experience is the most important determinant of risk. The lowest complication rates are at major centers that perform this type of highly specialized surgery on a weekly basis.

ADVERSE EFFECTS OF STIMULATION
The process of programming the device is tedious and sometimes uncomfortable for the person with PD. Individuals are often asked to withhold their medication for several hours while the stimulator personnel determine the optimal device settings. It may take hours of testing different electrode combinations before the best setting is found. Sometimes, during a programming session, individuals may experience temporary tingling or shocking sensations, and uncomfortable muscle spasms or contractions.

Additional stimulator-induced problems may include balance impairment, dizziness, speech difficulties or a general vague sensation of
"not feeling right." There are rare reports of stimulation-induced feelings of depression, despair or impulsive behavior. Deep brain stimulation can also induce dyskinesias that resemble the dyskinesias caused by levodopa.

**TABLE 5. REVERSIBLE ADVERSE EFFECTS OF STIMULATION**

- Jolting or shocking sensations
- Numbness or tingling, often in the face or hand
- Dizziness or balance impairment
- Twisting movements that resemble dyskinesias
- Muscle spasms, usually in the face or hand
- Slurred speech
- Double vision
- Depression

All stimulator-induced effects are temporary and reverse promptly with a change in the DBS settings. After a programming session, it is a good idea for individuals to wait at the center for an hour or so before returning home just to make sure that the new stimulator settings are well-tolerated and free of adverse effects.

People with PD with implanted deep brain stimulators are generally allowed to participate in any physical activity they choose. However, it is important to use common sense and not to engage in activities that could subject the device or wires to a direct physical blow or acceleration. Examples of specific activities that could potentially harm the stimulator include contact sports or chiropractic neck manipulation. Sometimes, with repeated trauma, the connecting lead or the battery erodes through the skin, requiring replacement.

Deep brain stimulators may switch off by accident if an individual walks through a magnetic field, such as a security device or theft detector. This is simply an inconvenience and carries no permanent risk to the person with PD or stimulator device. When the stimulator switches off, however, PD symptoms can immediately return. If this happens, the person with PD may re-activate the stimulator using the handheld device. The manufacturer provides a list of appliances that may cause interference with deep brain stimulation.

There is an important warning that people with PD with implanted brain electrodes should not undergo ultrasound diathermy, a treatment that involves applying a heating coil to the skin. It is also recommended that individuals with deep brain stimulators check with their neurologist before undergoing magnetic resonance imaging (MRI) scans, a technique that uses a powerful magnetic field. In theory, the DBS electrode is unaffected by magnetic fields, but some of the larger MRI scanners are very powerful.

In case of questions about the stimulator, individuals should always contact their treating neurologist, who may recommend a return visit to the medical center for a device check.
FUTURE PERSPECTIVES on Surgery for PD

Deep brain stimulation is the most advanced surgical approach currently available for Parkinson's disease. For some people with PD, the procedure is miraculously effective. Individuals who once experienced disabling tremors, severe dyskinesias or paralyzing wearing-off episodes may find themselves free of their former disabilities. For many others, however, deep brain stimulation does not solve their problems.

Deep brain stimulation is a new technology and will almost certainly improve over time. In the next few years, improvements in battery technology will bring batteries that are smaller, longer-lasting and rechargeable through the skin by an external magnetic signal. A second DBS system will become available, creating a competition that will speed the pace of new progress. Anticipated changes include an alarm feature that lets the people with PD know when the device is malfunctioning; advanced troubleshooting features; and the ability to program the deep brain stimulator over the telephone or Internet so that people with PD do not have to return to the office for these adjustments. Someday, the entire apparatus, including the generator, will be miniaturized and implanted in the skull, eliminating wires and batteries in the neck and chest.

In recent years, the field of DBS has seen a number of important trends. The literature reports that some younger people with PD with dyskinesias and wearing-off fluctuations have undergone surgery at an earlier stage of their disease, instead of experiencing years of medication adjustment. New targets for the DBS electrodes are being explored to help symptoms of PD. One deep brain site, the pedunculopontine nucleus, has generated interest as a potential target for treating gait freezing. And DBS is increasingly being tested as treatment for other diseases of the nervous system, such as dystonia syndromes, depression, Tourette syndrome, and obsessive compulsive disorder. All of these new approaches are the topic of ongoing study, and no final verdict has been reached.
As deep brain stimulation becomes more sophisticated, the stimulating electrode will have motion sensors that allow it to detect when a person with PD wants to make a specific movement. The stimulation electrode in current use has four electrical ring contacts arranged in a line. Electrodes of the near future will have an improved ability to direct electrical current into brain tissue, improving stimulation effectiveness while reducing side effects. Someday, the stimulators will have more contacts and branch leads implanted in other parts of the basal ganglia to produce network effects that more closely resemble the physiology of the person’s motor system.

Other futuristic possibilities beyond DBS may include the surgical implantation of cells with regenerative capacity; gene therapies; and other treatments that can prevent or reverse the cell loss in PD.

**TEN Commonly-Asked Questions**

1. **Who is the ideal candidate for surgery?**
   The ideal candidate for surgery is a person with PD who responds well to individual doses of levodopa and other anti-parkinsonian medications but who experiences tremors, dyskinesias, or wearing-off spells. Such individuals usually have had the disease for 10 years or more and have reached a stage where even a complicated medication schedule, sometimes requiring pills every two hours or less, is not sufficient to control the wearing-off episodes.

   People who never experience clear benefit from levodopa are unlikely to improve with deep brain stimulation, and therefore should not consider this approach. People who have an atypical form of parkinsonism, such as progressive supranuclear palsy (PSP), will also not benefit from surgery. To be a candidate for the operation, individuals must be in good general physical and psychiatric health, have no cognitive impairment, and have a good support system of family or friends to help them through the ordeals of surgery and subsequent post-operative management.

2. **Does surgery help all symptoms of Parkinson’s disease?**
   Surgery for PD helps many, but not all, symptoms of PD. As a general rule, the symptoms that respond best to medication respond best to surgery. Tremor and rigidity can greatly improve with surgery, but slowness improves as well. Dystonic posturing of the limbs, often present in the early morning or during “off” spells, also responds well to surgery. Drug-induced dyskinesias may completely resolve after surgery. On the other hand, individuals who experience stooped posture, gait freezing, poor balance, cognitive impairment, or rapid stuttering speech, sometimes called tachyphemia, may not experience benefit in these symptoms after a surgical procedure.
3 Which is the best choice of deep brain stimulation for me?
The choice of which surgical technique is best for a given individual — and indeed, the decision to have surgery at all — depends on many factors. No two people with PD are alike. For most people with PD, the chance of significant benefit must clearly outweigh the operative risks. The choice of surgical approach is best determined through careful discussions involving the person with PD, the family, the neurologist and the neurosurgeon.

The choice of surgery may depend on the person’s specific symptoms. Is the main issue a disabling tremor? Or is drug-induced dyskinesia the biggest problem? Other pertinent questions include: Has the individual had previous brain surgery? Does he or she live in an area that offers ready access to the medical center for DBS programming or troubleshooting? The techniques with the most benefit appear to be deep brain stimulation in the subthalamic nucleus (STN) or globus pallidus (GPI) but there are people with PD for whom a different approach may be preferable.

4 Where is the best place to have surgery?
Although enthusiasm for surgery is widespread, the techniques are very specialized and the necessary surgical skills and support systems are not available everywhere. For this reason, people with PD and their families are wise to seek out a center that has long-standing experience with DBS as well as resources specifically dedicated to the surgical treatment of PD. As with any complicated technical procedure, there is a learning curve, and centers with the most experience have the lowest complication rates.

The ideal center should have a clinical team devoted to the surgical treatment of PD, with a neurosurgeon specially trained in stereotactic surgery and an electrophysiologist to perform intra-operative brain mapping. There should be experienced neurologists and nursing personnel skilled in pre-operative screening and post-operative care, including programming the deep brain stimulator. It is essential that center personnel be available for immediate advice and evaluation should the need arise.

Considering the rapid pace of technological advances in this field, it may be worth considering whether the surgical center has a serious commitment to PD research, or whether the surgery is being offered simply to provide a clinical service. One telling question may be: does the surgical team regularly publish and report its results and complications to the medical community?

5 Does my insurance cover the cost of the surgery?
Most private insurers, as well as Medicaid and Medicare, will cover the expenses of deep brain stimulation surgery, including the operation, anesthesia, neuroimaging, hospital care, physician's fees, and the stimulator devices. Medicare covers 80 percent of the cost of the surgical procedures; for most individuals, the remaining 20 percent is provided by a secondary insurance carrier. Individuals with no secondary medical coverage are advised to speak with the administrator at their surgery center. Some individuals who belong to a strict health maintenance organization (HMO) may have initial difficulty obtaining approval for the surgery if the surgical center does not participate in their medical plan, or if the hospital is out of the plan’s network. But do not give up! It is almost always possible to obtain insurance carrier approval for the surgery by demonstrating medical necessity. The surgical center can be very helpful in assisting patients with their insurance plans; sometimes a letter from the treating neurologist or neurosurgeon is required. It is important to note that deep brain stimulation was approved by the FDA in 1997, and again in 2002, so the procedures are now considered standard therapy that should be covered by all medical insurance carriers.

6 Will surgery enable me to stop my anti-parkinsonian medications?
For many people with PD, DBS surgery will reduce the dependency on medication. Individuals who undergo bilateral subthalamic nucleus stimulation, for example, may reduce their medication by 50 percent or more in the months following surgery. For individuals who experience adverse effects of their medications, such as hallucinations or dyskinesias, limiting medication intake represents an important secondary ben-
efit of the operation. Individuals whose main problem is severe
tremor may find their tremor so well controlled by surgery that med-
ication becomes unnecessary.

7 What is the effect of surgery on the long-term course of PD?
The effect of surgery on the prognosis of PD is unknown. Most
investigators believe that DBS has little or no effect on slowing the
progression of the disease, even though relief of symptoms may be
dramatic and long-lasting. Studies have shown benefits lasting at least
five years for tremor and dyskinesia. But other disabling symptoms of
PD — gait impairment, falling, poor posture, soft speech — may
worsen with time, despite surgery. As for the possibility of dementia,
the long-term effect of surgery is unknown.

8 Will a decision to undergo surgery now disqualify me from better
treatments that might be available in the future?
It is impossible to predict what new or improved alternative therapy
might be coming in the near future, or who will be eligible for it.
Deep brain stimulation, unlike earlier techniques, does not destroy
significant amounts of brain tissue and is therefore, in theory, a
reversible treatment. As such, having DBS done now should not
exclude an individual from a future, more promising therapy.

9 Is surgery for Parkinson’s disease a cure?
No — at least, not yet. A cure for PD would be a treatment that can
stop the disease from progressing, and even reverse it. Neither deep
brain stimulation, nor medications, nor any gene-based or cell trans-
plant technique can provide this at present. At best, surgery may be
able to control some or all of the disabling problems of PD, such as
drug-induced dyskinesias, tremor, wearing-off fluctuations, slowness of
movement, rigidity and tremor — but the disease remains progressive.

10 What are the chances of finding a cure for PD?
Many scientists believe that the cure for PD will come from a deeper
understanding of what causes the disease. What is the reason that
dopamine neurons in the basal ganglia begin to degenerate and die? If
the cause of the neurodegeneration can be identified, perhaps a specific
treatment could be applied to slow, stop or reverse its process.

Strategies of treatment in the future may include the delivery of sub-
stances or genetic material directly to degenerating brain cells. Future
treatment may involve replacing dying cells using an alternative source
of brain tissue, such as stem-cell lines or embryonic tissue. However,
these techniques are in the earliest stages of development.

For people with Parkinson’s disease and their families, the progress is
always too slow. But there are reasons to be optimistic. DBS revolu-
tionized the treatment of PD and has improved the quality of life for
thousands of people with PD. It is anticipated that in coming years
many scientific advances will be translated into benefits for people with
Parkinson’s and so the hope for a cure is linked with true promise and
great optimism.
WE APPRECIATE YOUR FEEDBACK!

If you have comments or suggestions on the material in this booklet or on how we can better serve you, please use this form to send us your feedback.

You are not required to include your contact information unless you would like PDF to respond to your comments.

Name: __________________________________________

Telephone: _______________________________________

Email: ___________________________________________

☐ Yes, I would like PDF to contact me regarding my comments.

The best way to reach me is by ☐ phone ☐ email.

Comments on the material included in this booklet:
_________________________________________________

_________________________________________________

Suggestions for additions or changes to this booklet:
_________________________________________________

_________________________________________________

Please fax this form to:
(212) 923-4778

Or mail to:
Parkinson's Disease Foundation (PDF)
RE: Deep Brain Stimulation booklet
1359 Broadway, Suite 1509
New York, NY 10018

If you have or believe you have Parkinson's disease, then promptly consult a physician and follow your physician's advice. This publication is not a substitute for a physician's diagnosis of Parkinson's disease or for a physician's prescription of drugs, treatment or operations for Parkinson's disease.
The Parkinson's Disease Foundation® (PDF®) is a leading national presence in Parkinson's disease research, education and public advocacy. We are working for the nearly one million people in the US living with Parkinson's by funding promising scientific research and supporting people with Parkinson's, their families and caregivers through educational programs and support services.

Since its founding in 1957, PDF has funded over $70 million worth of scientific research in Parkinson's disease, supporting the work of leading scientists throughout the world.

Main Office
1359 Broadway, Suite 1509
New York, NY 10018
P: (212) 923-4700
F: (212) 923-4778

Columbia University Office
710 West 168th Street
New York, NY 10032

Midwest Office
833 W. Washington Blvd.
Chicago, IL 60607
P: (312) 723-1833

(800) 457-6676
info@pdf.org
www.pdf.org