Deep Brain Stimulation (DBS)

Introduction

Deep brain stimulation (DBS) has evolved as an important and established treatment for movement disorders. While DBS is not a cure for movement disorders, it can successfully treat symptoms by disrupting the abnormal patterns of brain activity that become prominent in these diseases. Using a fully implantable neurostimulation system, DBS provides a targeted, adjustable, non-destructive, and reversible means of modulating the pathological of brain circuits. Patients with Parkinson's disease, essential tremor, dystonia, and other movement disorders such as Tourette syndrome, who do not obtain a satisfactory response from optimal medical therapy, may be considered candidates for surgical intervention.

In the past, the neurosurgical treatments consisted chiefly of procedures that produced lesions to selected areas of the brain in order to control the movement disorder ("ablative surgery"). These procedures involved making an incision in the scalp, drilling a hole through the skull, and then advancing a "probe" (electrode) into the portion of the brain that was thought to be functioning abnormally. Heating the tip of the electrode then resulted in lesioning the target brain area to produce a reduction of the abnormal or involuntary movement on the opposite side of the body. Although effective in most cases, risks included weakness on the opposite side of the body, numbness, poor coordination, speech disturbance and other complications. These potential risks are compounded when the procedure is performed bilaterally (on both sides).

Deep brain stimulation (DBS), has replaced the traditional ablative procedures, as the surgical treatment of choice for a variety of movement disorders such as
Parkinson's disease, tremors, dystonia, and tics. As a result of improved understanding of the anatomy and function of the basal ganglia, (the part of the brain involved in Parkinson's disease and other movement disorders), coupled with refinements in imaging and surgical techniques, DBS is gaining wide acceptance as a chronic treatment of not only tremor, but also other symptoms of Parkinson's disease, complications related to levodopa therapy, such as motor fluctuations and dyskinesias, and other movement disorders such as dystonia. The major advantage of DBS over the traditional ablative procedures is that the stimulating electrodes and parameters (frequency of stimulation, pulse width, and amplitude) can be adjusted and "customized" to the needs of the individual patients.

Since the early 1990s, clinicians from around the world, including those at Baylor College of Medicine, began to explore different brain targets to control the various movement disorders. The current data, based on the extensive experience at Baylor and abroad, provide compelling evidence that chronic, high-frequency stimulation of the ventral intermediate (VIM) nucleus of the thalamus, the subthalamic nucleus (STN) and the globus pallidus (GPi) improves essential tremor and tremor in Parkinson's disease. The STN and GPi control not only tremor, but also motor slowness, rigidity, gait, and, most importantly, levodopa-related motor fluctuations and dyskinesias in patients with moderately advanced Parkinson's disease.

DBS is currently being used in selected centers around the world, including the Baylor College of Medicine, to treat a variety of movement disorders. In collaboration with Dr. Viswanathan, from the Department of Neurosurgery, we have implanted over 500 DBS devices. Patients interested in being evaluated to determine whether they are candidates for DBS should contact the Parkinson's Disease Center and Movement Disorders Clinic, Baylor College of Medicine, Department of Neurology (713) 798-2273.
Benefits and Limitations of Surgery

Parkinson's Disease

In patients with Parkinson's disease (PD), surgery is generally recommended at a time when medications cannot adequately control symptoms. Patients are most often referred for deep brain stimulation (DBS) surgery when they have experienced problems with dyskinesias (excessive involuntary movements that occur as a consequence of PD medications) and fluctuations (the beneficial effects of medications do not last long enough between doses). When there are no further adjustments that can be made with medications because of these problems, surgery may be a way to limit complications from medications and to improve motor function. It is important to note that surgery will NOT work any better than medications ever did. The major benefits of DBS surgery in this case are to decrease "off" time and to reduce or eliminate dyskinesias. Additionally, many patients report that their quality of life improves substantially after DBS. Medications can be gradually reduced after DBS, but this is not always the case and may depend on many factors.

In PD, motor symptoms (tremor, rigidity, slowness/incoordination, walking/balance problems) that do not get better with medications will generally not get better following DBS surgery. The only exception is when the surgery is being primarily done to control tremor that has failed to improve with medications. Additionally, DBS is NOT a cure for PD, and it probably does not slow or stop the underlying progression of the disease. Some symptoms such as balance difficulties, speech problems, swallowing difficulties, and cognitive decline develop or worsen as PD progresses, and cannot be addressed with DBS adjustment. Finally, the non-motor complications of PD, such as depression, problems with thinking or memory, constipation, urinary changes, or pain, are also not likely to be markedly improved by DBS. It is absolutely imperative that patients have realistic expectations and a clear understanding about the anticipated outcomes and potential risks before consenting to the procedure.
Essential Tremor and Dystonia

Patients with essential tremor (ET) or dystonia (including cervical dystonia or torticollis) can reasonably expect that their tremors or involuntary muscle contractions or postures can be better controlled with DBS than with medications alone. However, there may be several factors that influence how well this can be done, including individual patient characteristics, duration of disease, and distribution of symptoms. DBS surgery will not help with balance problems or other associated features such as neuropathy or hearing loss. Tremors of the head or trunk are more difficult to treat but can improve.

Tourette Syndrome

Patients undergoing treatment for Tourette syndrome (TS) should be aware that DBS in this condition is still under investigation and there are no guarantees about the outcome. In our experience to date, tics can substantially improve, but they do not go away completely. There may also be some improvements in co-morbidities such as obsessive-compulsive disorder and attention deficit disorder. Surgery is generally reserved for severe cases in which all medical and psychological therapies have been exhausted and unsuccessful.

Risks Associated with DBS Surgery

There are potential risks associated with any brain surgery, including infection, intracerebral bleeding, leaks of the fluid surrounding the brain (cerebrospinal fluid), strokes, headaches seizures, weakness, sensory changes, technical problems, wound healing problems, disfiguring scars, prolonged hospitalization, and need for additional surgery. Additionally, there may be potential risks associated with receiving anesthesia. The percentage of patients who report or experience these complications is low, but may be different according to the surgeon that is performing the procedure. It is a good idea for patients to discuss individual complications rates with their neurosurgeon.
Additionally, there may be potential risks related to the programming of the DBS device, which begins a few weeks after the surgical process is complete. When making adjustments to the DBS, there may be immediate short-lived side effects such as tingling, tightening sensations, visual changes, or speech problems. Much of the time, these may be eliminated by further DBS adjustment. However, certain effects may not become apparent until hours or days after the adjustment. These may include any of the above symptoms, but also mood or behavior changes, involuntary movements, worsening of the underlying symptoms, or walking and balance problems, including falls. Patients undergoing DBS for ET, especially if the procedure is done on both sides of the brain, are particularly prone to developing problems with speech or gait/balance changes. It is important that these problems are communicated to the neurologist if they occur so that they can be rectified as soon as possible. There may be several ways that these problems can be addressed, but it is possible that the changes required to minimize such side effects will lead to less symptom control.

Less commonly, and in the long term, there may be device complications that include loss of effect, unexpected side effects, fracture or breakage of the wiring, change of position of the electrode within the brain, or infection. Some of these problems, if they develop, may require removal of the device or portions of the device.

**Patient Selection for DBS Surgery**

There is a preoperative process that all patients being considered for surgery will undergo, but this differs according to the condition being treated.

**Parkinson's disease**

The patient and his/her neurologist will decide together when it is time to consider DBS. All patients will undergo an "on/off" evaluation in which their PD symptoms are assessed under conditions of no medication ("off"), and again with the full/maximal effect of medications ("on"). This is done by asking the patient to come
in for evaluation first thing in the morning without having taken any PD medications. The neurologist will make an assessment of symptoms and document a physical exam on video. The patient will then take his/her usual first dose of medications. Once this dose has "kicked in" another assessment of symptoms will occur with another video documentation. This is done in order to gain a better understanding of which motor symptoms improve with medications which helps guide patient expectations of outcomes after DBS, and to ensure that DBS really does have some benefit to offer an individual.

Patients are also required to undergo a neuropsychological assessment to gain a better understanding of their baseline thinking skills and psychological state. Symptoms of depression or anxiety should be appropriately addressed prior to undergoing brain surgery. The presence of cognitive problems, such as dementia, may indicate a patient who is at risk of further cognitive decline after DBS, leading to more disability. Furthermore, the presence of dementia produces practical obstacles to achieving optimal outcomes. Patients with dementia may have difficulty accurately observing and articulating their symptoms, making adjustment of DBS parameters more difficult. Neuropsychological evaluation before surgery also provides an important baseline assessment; in cases where cognitive or emotional problems occur after surgery, the testing can be repeated and compared to preoperative scores to help determine the cause of the problems.

Essential tremor
Preoperative assessment of tremor severity by formal scales is usually done so that the neurologist has a baseline against which to measure the response to DBS. ET patients are also asked to undergo preoperative neuropsychological assessments for the same reasons as outlined above.

Dystonia
Preoperative assessments of dystonia symptoms are done for reasons similar to those in ET patients. Neuropsychological assessments may also be considered.
Tourette syndrome
Preoperative video evaluation, tic rating scales, and neuropsychological assessments are obtained before surgery. In some cases, a psychiatric evaluation is required. These and other factors related to a patient’s social or psychological state and support network are considered together in determining if DBS is appropriate.

All cases are reviewed at a consensus conference attended by the treating neurologist, neuropsychologist, and neurosurgeon, at which time recommendations are made for or against surgery, and regarding which brain location should be stimulated. All patients will receive a follow-up call from their neurologist explaining whether surgery was recommended or not, and which location of stimulation was thought to be most beneficial. Patients will have an opportunity to ask further questions at this point before proceeding with actual surgical appointments.

**DBS Surgical Procedure**

DBS electrode placement is typically done in the awake patient using a stereotactic frame. In this procedure, a rigid frame, or halo, is attached to the patient’s head just before surgery after the skin on the scalp is anesthetized with a local anesthetic. A brain imaging study is obtained with this frame in place and the images are used to calculate the position of the desired brain target and to help guide instruments to that target with minimal brain trauma. The stereotactic frame is then fixed to the operating table, a patch of hair is shaved and the scalp is washed. After making the scalp completely numb, an incision is made and a small opening in the skull is created.

The DBS lead (a thin wire), which contains four electrodes, is then surgically inserted into the desired target and tested to verify optimal placement. The lead is ultimately connected to an extension wire that passes from the scalp area under the skin to the chest. Here it is connected to an implantable pulse generator (IPG), a pacemaker-like device, which can deliver pulses with a variety of parameters,
modes, and polarities to the target brain area. The IPG is surgically implanted under the skin in the upper chest area near the collar-bone or under the skin in the lower abdomen, much like a pacemaker. The IPG delivers continuous electrical pulses through the electrodes to produce the desired effects of DBS stimulation.

The patient can activate or deactivate the DBS system by placing a magnet over the chest area that contains the IPG. The IPG is a metal "box" about two inches in diameter and about 1/2 inch thick, similar to a cardiac pacemaker. It contains a small battery and produces the electrical pulses needed for stimulation. The typical battery life is expected to be approximately five years, but this may vary depending on the individual settings and hours of use per day. The battery cannot be replaced without replacing the entire IPG. Replacing the IPG involves minor surgery. This needs to be done every 3-4 years. The Activa® RC Neurostimulator (Medtronic) is available and is the first rechargeable DBS neurostimulator. It has an expected battery life of 4-9 years and patients can choose daily or weekly battery recharge options.

**DBS Programming After Surgery**

A few weeks after surgery, the movement disorders specialist will use a hand-held programmer to test different electrodes and determine the settings that provide the most benefit with the least side effects. This initial programming session after DBS surgery can last around one hour. This guides future programming sessions, which are usually performed every 3-4 weeks for at least 2-3 more visits to determine the optimal settings for stimulation.

Patients should be aware that DBS is not a cure for Parkinson's disease and the IPG settings need to be adjusted in subsequent programming sessions. During the follow-up DBS visits, there will be a fee for the adjustment and reprogramming of pulse generator (CPT code 95971, 95974, 95975) for stimulator adjustment and for a routine follow-up visit. It is our policy that we require payment at the time of
service (except for Medicare patients). We do, however, provide assistance in filing for Medicare/Third Party Payer reimbursement.

Common Questions about DBS Surgery

1. How long will I need to stay in the hospital and what is the recovery time?

If DBS is planned for both sides of the brain, there will be two surgeries approximately 7-14 days apart. The total time for the first day is typically 6-8 hours, and includes anesthesia evaluation, placement of a stereotactic frame (see #2 below), brain imaging, surgical planning, placing the electrodes, and time in the recovery room. An overnight stay in the intensive care unit is required for monitoring. The next morning, a brain scan is performed to check for complications and electrode location. Patients are discharged home provided they are feeling well and there are no problems seen on the scan. If any difficulties are experienced, the hospital stay may be extended by an extra night or two, or longer, depending on the cause.

The second surgery is to implant the pulse generator (IPG), which also contains the battery and connect it the wires that are already in the brain. This is typically done 1-2 weeks later as an outpatient day surgery, and takes about two hours. Patients go home that same afternoon or evening.

If a unilateral (one-sided) surgery is planned, the entire procedure (electrode implantation and battery placement) can be done on a single day, and will take about 4-6 hours.

There are no formal recovery or rehabilitation recommendations after DBS surgery. The surgeon will provide care instructions for the incision sites, prophylactic medications, and activity restrictions at the time of discharge after each procedure. Patients are advised to "take it easy" and to use common sense and their best judgment about returning to work or other usual activities.
The DBS is turned on at the first programming session, about four weeks after the electrode implantation to allow for any potential swelling to subside. Early activation before return to an established postoperative state may result in insufficient programming or side effects.

2. How long do I have to wear the halo?

A "halo" is a metal stereotactic frame placed on the head that is required by the neurosurgeon to optimize placement of the electrodes inside the brain. This is typically attached to the skull the morning of the surgery and is kept in place until the electrode placement surgery is complete. If patients are uncomfortable with the halo, the Anesthesiologist can administer medications to ease the discomfort.

3. Will I be awake for the surgery?

Most patients are kept in a state of conscious sedation so that they are comfortable during the procedure. However, this sedation is lifted during the time that the electrodes are being placed in the brain so that the neurosurgeon can hear the electrical activity of the brain (microelectrode recording). After the target brain structure is reached, the targeted brain structure will be stimulated with electricity while the patient is asked to perform simple tasks to assess the degree of symptom control and for side effects. These steps are also essential to ensuring that the electrodes are placed in the best location to address the condition.

In some cases, it may be recommended that the electrode surgery be performed under general anesthesia. Additionally, patients participating in certain research protocols may also undergo the surgery under general anesthesia, and with MRI guidance only. No testing or microelectrode recording are performed in these situations.

During the surgery where the battery is placed and connected, general anesthesia is used.
4. Does the surgery hurt?

The brain is the only part of the body that has no sensation, so even though conscious sedation is used, patients do not feel the electrode being inserted. There may be some sensations of pressure as the holes are made in the skull through which the electrodes are placed. However, most people say that the most uncomfortable part of the procedure is when the halo is placed. There will likely be some soreness over the incision sites after each surgical procedure.

5. Will I need to shave my head for the surgery?

At minimum, a portion of the scalp will need to be shaved on either side in order to ensure clean access to the brain for the neurosurgeon and to prevent infections. Some patients and some surgeons prefer to shave the whole scalp, but this can be discussed on an individual basis with the neurosurgeon.

6. When do I return after the DBS surgery?

If staples are placed, these will need to be removed by the neurosurgeon about two weeks after the surgery. This appointment will be coordinated before hospital discharge. In some cases, absorbable sutures may be used and such an appointment will not be necessary.

The first programming session in the neurologist's office takes place about four weeks after the electrode surgery, and is scheduled once the OR (operating room) date is finalized. It is imperative for patients with PD to present to the neurologist's office OFF all PD medications only beginning at midnight the night before for ALL programming sessions. This is the only way to assure that effects and side effects are coming from the DBS alone.

We will make every effort to coordinate visits for our out-of-town patients.
7. Will my medicines change when I leave the hospital?

Medications for the neurologic condition or general health issues will not change after surgery. Patients are usually given an antibiotic and possibly a medication to prevent seizures after brain surgery. PD medications are not adjusted until after the first programming session.

8. Are there any restrictions after surgery?

Immediately following surgery, the surgical area should be kept dry until after the stitches or staples are removed. Heavy lifting or over-strenuous activities should be avoided. Specific care instructions for the surgical sites will be provided at the time of hospital discharge.

Once the electrodes and battery are implanted, it is not safe for patients to undergo body MRI scans. Brain MRIs can be performed safely under specialized protocols. The appropriate specifications are in place at the Baylor Clinic Radiology suite, but are not reliably in place elsewhere. Please contact us directly if such scanning is requested by other doctors.

Patients should not undergo diathermy after DBS implantation. Diathermy is a technique used in physical therapy in which deep heating of tissues is accomplished by a high frequency electrical current. Ultrasonic treatments or investigations without diathermy can be performed. Patients should check with their neurologist first if a therapist is recommending this type of treatment.

9. How do I activate or adjust the device?

Initial device activation must be performed in the neurologist's office at the first programming sessions. This is not done immediately after surgery to allow time for the brain to recover from the procedure itself. All patients undergoing DBS will have a control device that allows them to turn the system on and off, and check the status of the battery. This capability will be explained at the first programming appointment. Depending on the particular condition and situation, and only with
certain battery types, the neurologist may program the device to allow the patient to adjust specific parameters at home.

10. How many programming sessions and follow-up appointments will I need?

After the first programming session, patients should expect to come in every 3-4 weeks for at least 2-3 more visits to optimize DBS settings, then at six months, and then annually. In PD cases, it generally takes about six months to go through the process of DBS and medication adjustment. For ET, this process may be shorter. For dystonia and TS, this process will probably take longer. Each case is different, but regardless of the situation, this process should not be rushed because it may take a few days or weeks to see the full effect of a programming session.

11. Can I get an MRI scan?

As mentioned in #8 above, once the electrodes and battery are implanted, it is not safe for patients to undergo body MRI scans. Brain MRIs can be performed safely under specialized protocols. The appropriate specifications are in place at the Baylor Clinic Radiology suite, but are not reliably in place elsewhere. Please contact us directly if such scanning is requested by other doctors.

A brain MRI scan to check the electrode location is often scheduled at six months or if unexpected difficulties are encountered with programming. These are performed on alternating Friday mornings at the Baylor Clinic.

12. Who do I call if I have questions or problems?

All questions related to preoperative neurological evaluations, programming appointments, DBS adjustment, medication adjustment, and the underlying neurologic condition should be directed to the neurologist's office:

Dr. Joseph Jankovic, Dr. Joohi Jimenez-Shahed, and Dr. Arjun Tarakad
Parkinson's Disease Center and Movement Disorders Clinic
Baylor College of Medicine  
Phone: (713) 798-2273

All questions related to surgery scheduling and care of the surgical site should be directed to the appropriate neurosurgeon's office:

Dr. Ashwin Viswanathan  
Department of Neurosurgery  
Baylor College of Medicine  
Phone: (713) 798-4696  
Email: ashwinv@bcm.edu

All questions related to preoperative neuropsychological assessments should be directed to the Division of Neuropsychology:

Dr. Michele York and Dr. Adriana Strutt  
Division of Neuropsychology  
Baylor College of Medicine  
Phone: (713) 798-8673

Any technical or service questions related to the device can be directed to the manufacturer:

Medtronic Patient Services  
Phone: (800) 510-6735

Selected References


Thenganatt MA, Jankovic J. Recent advances in understanding and managing Tourette syndrome. *F1000Research.* 2016;5.


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