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Long-Term Surgical and Hardware-Related Complications of Deep Brain Stimulation

Paresh K. Doshi

In-charge Stereotactic and Functional Neurosurgical Program, Jaslok Hospital and Research Centre, Mumbai, India

Key Words

Deep brain stimulation complications · Hardware complications · Deep brain stimulation surgical complications

Abstract

Objective: To evaluate the incidence of surgical and hardware-associated complications of deep brain stimulation (DBS) for a range of movement disorders. ***Methods:*** The study design is a retrospective analysis and review of surgical and hardware complications of DBS performed by a single surgeon from 1999 to 2009. A total of 153 cases of DBS (298 electrodes) for various movement disorders and a minimum follow-up of 1 year have been included. Two patients could not be implanted. A further 54 patients who underwent change of the implantable pulse generator (IPG) have been included for analysis of hardware-related complications. ***Results:*** The mean follow-up was 64 ± 36.15 (range = 12–129) months for the DBS group. Twenty-four (15.6%) patients developed complications. Confusion occurred in 3.9%, vasovagal attack in 1.9%, lead migration/misplaced lead in 2.5%, erosion and infection in 4.5% and IPG malfunction occurred in 1.4% of the patients. When calculated with respect to the number of electrodes and IPG replacements, the complication rate was lower (11.9%). Three patients had their system explanted, two of them being patients with dystonia who had inadvertently damaged their operative site. ***Conclusion:*** DBS surgery is a relatively safe surgery, with most of the complications being minor, without long-term morbidity. The complication rate in elderly (age ≥65 years) is comparable to that in younger patients. However, confusion is more frequent in this age group, and patients and relatives can be prepared to accept this as a transient morbidity.

Deep brain stimulation (DBS) is an established procedure for the treatment of movement disorders. More than 75,000 DBS procedures have been performed around the world for various indications ranging from pain to psychiatric disorders [pers. commun., Medtronic Database]. DBS offers a distinctive advantage over lesioning procedures in terms of reversibility and titratability. However, as with any implantable system, DBS may result in a unique set of complications. Some of the complications are related to surgical procedures, particulary to neurosurgery [1, 2], while others are specific to DBS such as hardware complications [3–5] and stimulation-induced side effects that are unique to DBS. Most of the literature on surgical and hardware complications was published before 2007, except for two studies from Asia [6, 7].

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Dr. Paresh K. Doshi, MCh
In-charge Stereotactic and Functional Neurosurgical Program
Jaslok Hospital and Research Centre
15, Dr. G. Deshmukh Road, Mumbai 400026 (India)
Tel. +91 22 6657 3185, Fax +91 22 6657 3264, E-Mail pareshkd@gmail.com

Table 1. List of different surgeries and indications according to our patients (n = 153)

	STN			V_{im}		GP_i		Not implanted
	unilateral	bilateral	revision (3 electrodes)	unilateral	bilateral	unilateral	bilateral	
Parkinson's disease		132	2	2				1
Tremors				2	5			1
Dystonia						2	6	

A retrospective analysis of complications in 153 patients undergoing DBS surgery for movement disorders between 1999 and 2009, by a single neurosurgeon (author), is presented. Twenty-four (15.6%) patients developed surgical or hardware-related complications. This analysis has three salient features. First, DBS has been performed across all age groups, the youngest patient being 13 and the oldest 85 years of age. Second, most of the patients underwent bilateral simultaneous implantation of electrodes, and the third is a large cohort (40 patients) of elderly patients included in the analysis.

Patients and Methods

Study Design

Various movement disorders that were treated by DBS, including Parkinson's disease (PD), primary and secondary dystonia, tardive dyskinesias, torticollis, essential tremor, Parkinson's tremor, multiple sclerosis tremor, rubral tremor and poststroke tremor, are considered in this analysis. Retrospective case notes review was performed for all patients to find out if there were any intra- or postoperative complications. Follow-up records of all patients were available as they usually made one visit to the center every year for the management of their disease. A minimum period of 1 year of follow-up was considered necessary to determine the majority of surgical and hardware complications. This research project was approved by the scientific and ethics committee of Jaslok Hospital and Research Centre.

Demographics

A total of 298 electrodes were implanted in 153 consecutive patients who underwent DBS between 1999 and 2009. The age range was from 13 to 85 years. The mean age was 56.35 ± 12.0 years. There were 40 patients aged 65 years or more. There were 102 males and 51 females (table 1). Three patients could not be implanted with an implantable pulse generator (IPG); 1 due to severe intraoperative confusion and 2 due to delayed intracranial hemorrhage (ICH). In addition, 52 cases with a change of the IPG are included in the analysis of IPG malfunction, infection and erosion rates. Case records were reviewed to obtain information about the age, sex, indication for surgery and complications.

Categorization

Complications were categorized under three sub-categories. Category I included complications of surgical procedure, e.g. seizures, confusion, respiratory problems, vasovagal attack, and ICH. Category II included hardware-related complications such as IPG failure, lead fracture, erosion, and infection. Category III included systemic complications such as general infection.

Surgical Technique

There have been several modifications in the surgical techniques during the past 10 years. The current surgical technique in use is described here, with comments on important modifications.

To ensure smooth surgery, the patient is explained the surgical steps and what to expect during surgery by the PD nurse and the resident doctor. An MRI is carried out a day prior to surgery. This gives freedom to plan beforehand and reduces operative time. Medtronic FrameLink software is used for trajectory planning. The trajectory is planned so as to avoid the ventricles, deeper sulci and blood vessels. The entry point is usually precoronal or at the level of coronal suture, 3–5 cm off midline. A CRW frame (UCHR model) is used for the surgery. The CRW frame allows for gantry tilt and intraoperative head fixation to a Mayfield clamp, in a position comfortable to the patient, thus improving patient cooperation. It is very lightweight and has a detachable front piece providing for airway access during emergency. On the day of surgery, the patient is given a bar of chocolate or a banana at 6.00 a.m. The stereotactic frame is fixed in the OR with an anesthetist monitoring the patient. The stereotactic CT scan is fused to the preoperative MRI to plan the trajectory. The image intensifier is positioned around the head and draped in a sterile manner. It is only removed on completion of surgery to preserve surgical field sterility. A C-shaped flap is raised so that the incision does not overlie the burr hole. Instead of opening the dura, the dura is pierced with microelectrode cannulae to minimize the incidence of pneumocephalus. Microelectrode recording (MER) using 3–5 channels is performed for the intraoperative localization of the target. Stimulation is performed only in the best MER trajectory. If this is not satisfactory, another trajectory is explored. Fluoroscopy is used only after confirming the final target by stimulation and before removing the exploring electrode. The DBS lead is implanted using the DBS cannula to avoid any movement along the trajectory. The DBS lead position is confirmed by fluoroscopy. The lead is secured by using the Medtronic burr hole cap that comes with the DBS lead. A subcutaneous pocket over the parietal eminence is

created to house the lead. A postoperative CT scan is carried out to define the lead location and rule out any complications. The lead location is further confirmed using co-registration with preoperative images. On the next day, the IPG is implanted in the infraclavicular region in the subcutaneous space. The main wound is not opened but a small incision is made over the subcutaneous pocket to access the lead for IPG implantation. Antibiotics are started intraoperatively and continued for 8 days postoperatively [8].

Programming of the IPG is commenced from day 3 or 4. Each electrode contact is tested for maximal improvement and side effect threshold. The contact (usually the 2nd or the 3rd) that has the largest therapeutic window is selected for permanent programming. Medicines are reduced slowly as the current thresholds are increased. Intravenous antibiotics are continued till the time of suture removal. By the time of discharge, most of the patients are on stable programming parameters and have a 30–40% reduction in their medicines.

Results

The follow-up period ranged from a minimum of 1 year to 10 years and 9 months. During this period, 54 patients underwent IPG replacement and their analysis is also included while evaluating the percentage of infection- and erosion-related complications. Except for 1 patient who had two complications, all complications occurred in different patients.

Category I (Surgical Complications)

Confusion. Six patients had intraoperative confusion. Of those, 2 patients were below 65 years of age. The confusion ranged from mild disorientation to marked disorientation along with total incontinence. In 5 patients, the confusion lasted from 1 to 4 days and in 1 case it went on for 1 week. The IPG implantation was carried out once the confusion had cleared. One 70-year-old patient aspirated during the state of confusion and had a protracted recovery. He did not get operated as the relatives were reluctant to take a second chance. The correlation between age and intraoperative confusion was found to be statistically significant (Fisher's exact probability test, $p = 0.04$). The confusion was more frequent during the exploration of the second side and was noted only in the patients undergoing subthalamic nucleus (STN) stimulation.

Vasovagal Attack. Three patients developed vasovagal syncope. All attacks occurred at the time of frame fixation. They manifested as transient loss of consciousness with a fall in blood pressure. The patients recovered within a few minutes and the surgery proceeded as usual.

Intracerebral Hemorrhage. There were 2 incidences of ICH. One was during physiological exploration in a female patient who had a small bleed along the electrode tract. She developed contralateral weakness of the upper limb. She had a cardiac pacemaker in situ for arrhythmias and also had associated hypertension. The other one occurred in the perioperative period, 12 h after surgery, in a 66-year-old female developing uncontrolled hypertension and secondary hemorrhage near the electrode contact point. Both patients survived. While the first patient had no permanent morbidity, the other one was left with hemiparesis.

Respiratory Distress. One patient developed acute stridor after unilateral electrode implantation. The surgery had to be abandoned and the other side was operated 2 weeks later.

Category II (Hardware-Related)

Inaccurate Lead Placement. Leads could not be accurately positioned in 4 cases of STN stimulation. One was due to pneumocephalus resulting in brain shift, 2 were due to marked intraoperative confusion not allowing us to complete neurophysiological target exploration, and in the fourth the exact cause could not be identified. Two of these patients opted for repositioning the leads, whereas the other 2, though the improvement was suboptimal, chose to manage themselves without undergoing repositioning. There were no instances of lead migration. All misplaced leads were off by less than 2 mm in AP or lateral directions, producing suboptimal response and/or limiting increase of stimulation (even in the bipolar mode) due to side effects.

Erosion and Infection. Seven patients developed various forms of infection or erosion-related complications. One patient had a wound breakdown over the connector site in the immediate postoperative period leading to infection, necessitating explantation of the entire system. One of the patients affected by dystonia opened up his chest wound, causing infection that led to system explantation. Another dystonia patient who came from a very poor socioeconomic background ignored a skin infection over the scalp wound which led to pus formation and resulted in explantation of the system; this occurred 2 years after the surgery. Two other patients developed an infection over the IPG site that was treated by explanting the IPG, treating the infection with antibiotics, and reimplanting IPG on the other side of the chest wall once the infection was controlled. The other 2 patients, with an infection over the IPG site, were managed conservatively. These 4 patients all had infections between 1 and 6 weeks after surgery.

Table 2. Complication rates in individual series and meta-analyses

	Hamani et al. [22] (737)	Seijo et al. [14] 130 (272)	Oh et al. [25] 79 (124)	Chan et al. [7] 55 (100)	Voges et al. [10] 262 (472)	Xiaowu et al. [24] 161 (259)	Kenney et al. [9] 319 (507)	Present series 153 (298)
Confusion	13.7	9.2+	NA	NR	NR	6.8	5.3	3.9%
VV att.	NR		NA	NR	NR	NR	2.5	1.9
All vascular events (EC+IC)	2.8	6.92 (3.3)	3.6 (2.3)	(1)	2.8	0.39	2.4	1.2 (0.66)
Lead migration	3.5%	3.8 (2.2)	5.1 (3.2)	1	2.8 (0.15)	1.24	3	2.5 (1.3)
Erosion and infection, %	3.4	3.8 (1.8%)	15	1	8.3	2	4.4	4.5 (2.7%)*
IPG malfunction	1.2	0	0	NR	0	0.3	2.4	1.4
Lead fracture	1	0.7 (0.36)	(4.8)	(2)	1.7 (0.8)	0	2.2 (1.3)	0

Number of patients (number of procedures in parentheses). NR = Not reported; NA = not applicable; VV att. = not reported separately; EC = extracranial; IC = intracranial. * Includes 54 IPG replacement procedures. + Not reported separately, clubbed as minor complications.

Malfunction of IPG. Malfunction of IPG occurred in 2 patients. This was manifested by a sudden loss of improvement. On interrogating the IPG, it was found to have reset. This could not be further reprogrammed and had to be changed. Both incidences occurred between 1 and 2 years of DBS in PD patients in the absence of very high stimulator settings.

Lead Fracture. Lead fracture was not encountered in this series.

Category III (Systemic)

Failure to Respond to Stimulation or Medical Treatment. Two patients who initially had a good response to programming lost their improvement in the postoperative period. The first patient, after an initial good response, showed a sudden decline in response that failed to respond to even large doses of levodopa. He was screened for all possible causes, including switching off of the IPG and systemic infection, but no cause was identified. He had speech disturbances preoperatively and hence could not communicate effectively. Two days later, it was found out that this was due to tooth infection and the symptoms resolved once the infected tooth was removed. In the second patient, it occurred at the time of discharge. This patient had come from a distant place and was concerned that he would not be able to manage without programming assistance. Once again, reassurance after finding out the cause resolved the issue.

Discussion

DBS surgery, like any other surgery, has a learning curve [6, 7]. The difference is that the entire team needs to be working together as in a military operation to make the procedure safe for the patient. Since patients are operated upon in an awake condition, their cooperation largely affects the outcome of the surgery, making effective coordination within the team imperative. Attention to minute details, such as the requirements and sensitivities of the patient, ensures full patient cooperation, which is extremely vital for achieving good outcome. Another interesting trend that was observed in the literature [9, 10] is that the complication rate decreased with an increasing number of patients operated, emphasizing the need for larger experience of DBS for each center. However, this could not be established in the present study when the patient groups were divided into two equal parts (Fisher's exact probability test, $p = 0.55$). However, major complications like inaccurate lead placement or aborting surgical procedure mainly occurred in the first half of the patients. Table 2 shows the complication rates in individual series and meta-analyses. The references for comparison in the table have been selected with the intention to represent a wider geographical distribution and have included early to most recent series, which had a minimum sample size of 50 patients [11].

The surgical procedure may have to be aborted for various reasons. The incidence ranges from 0.9 to 4.9% [2, 5, 12–14]. The reasons can be dislocation of the frame, pneumocephalus and brain shift, inability to find the target [15], or ICH. In the present series, the surgical procedure had to be aborted in 3 patients and 1 more patient could not be implanted with IPG. One patient developed acute respiratory distress and the frame had to be removed to give airway access to the anesthetist. Another patient became severely confused and the procedure had to be abandoned. The third patient developed small ICH and decided not to proceed for surgery. The fourth patient developed ICH after 12 h resulting in hemiparesis

and she chose not to get the IPG implanted. The incidence of 2.5% reported in this series compares well with the average incidence of 2.4% reported in the literature [10].

Intraoperative confusion has been reported in almost all series. The range varies from 5 to 33% [6, 9, 16–19]. In the present series, confusion occurred in 3.9% of the patients. Usually, the confusion lasts for 1 or 2 postoperative days, delaying the implantation of IPG. However, in 1 case it lasted for over a week. Confusion was found to be more common in elderly (12%) as compared to younger patients (1.6%). Confusion was also directly related to the time spent during exploration, as in most cases it occurred during exploration of the second side. In the 100 cases of STN stimulation reported by Goodman et al. [16], of the 81 cases that underwent bilateral implantation, 11 experienced confusion as compared to 2 patients of the 19 who underwent unilateral implantation. Hu et al. [6] found advanced PD (Hohn and Yahr stage $\geq$4) and bilateral simultaneous surgeries to be risk factors for predicting postoperative confusion, whereas age or number of MER trajectories did not reach statistical significance. To reduce the incidence of confusion, surgical strategies have been modified over time. One day prior to surgery, a preoperative MRI, is performed to shorten the operative time. This is done with the planning software (Framelink, Medtronic) to localize the target. In elderly patients a minimal number (2–3 per side) of MER trajectories is used. The physiological exploration is also performed quickly at an increment of 2 mm (as the spacing of the Medtronic 3389 lead is 0.5 mm, with 1.5 mm electrode height) in the trajectory with the best MER signals. This has helped to reduce the operative time and incidence of confusion.

Three patients had vasovagal attacks. A few studies [9] have mentioned this as a complication. To avoid any major morbidity of this complication, several measures are adopted. The patient is given a large banana or a bar of chocolate 3 h prior to surgery, frame fixation is done after obtaining IV access and starting a normal saline infusion, pulse and blood pressure are constantly monitored, frame fixation is done in a semi-sitting position on the OR table so that in case there is a vasovagal event the patient could be made to lie down immediately and, lastly, the patient is continuously engaged in some form of discussion by the anesthetist during pin fixation to identify any sudden change in conversation alerting impending vasovagal syncope.

ICH is the most feared complication of DBS surgery. The reported incidence ranges from 0.6 to 3.5% [9, 12, 17, 20–23] per electrode. Use of MER [10, 24], use of rigid cannula for lead insertion [15] and hypertension [25] are some of the factors that have been identified to be responsible for ICH. Similarly, some studies have not found any correlation between the number of MER trajectories and risk of hemorrhage [15, 26]. In this series, the incidence of ICH was 1.2% in the patients and 0.6% in the leads implanted. Most of the series had events during the operative procedure. However, in the present series only one hemorrhage occurred due to the actual operative procedure, whereas the other occurred as a result of secondary medical conditions, i.e. hypertension. Planning of the electrode trajectories is done very meticulously; particular care is taken to avoid F1-F2 sulcus, deeper sulci and the ventricles. A 2- to 3-mm distance from the ventricular wall is maintained, as this is the second most vascular area along the trajectory. The anesthetist carefully monitors the blood pressure and makes all efforts to maintain the mean arterial pressure below 100 mm Hg.

The complication rate of misplaced lead and lead migration ranges from 1 to 5%. In this series it occurred in 4 patients and in 1.33% of the electrode insertions. In 2 patients, the malpositioned electrodes were repositioned, whereas the other 2 patients chose to manage without getting it repositioned. In the literature, though the cause of misplaced leads was not always mentioned, it included intraoperative pneumocephalus, lack of availability of C-arm imaging, movement of the electrodes due to improper fixation and brain shift in various reported series. In this series, the lead was misplaced because of a lack of physiological response due to intraoperative confusion. This occurred in the first 75 cases of the series and has not occurred thereafter. Use of MER has been helpful in reducing this complication. The author now performs dural puncture with cannula rather than completely opening the dura, thus minimizing the risk of pneumocephalus. Retaining the MER cannulae to fix the brain while introducing leads also further prevents chances of brain shift. Use of fluoroscopy is essential to confirm accurate lead placement. There has not been any case of lead migration, though only the standard Medtronic burr hole cap was used to fix the lead. The author is very careful with the size of the burr hole and ensures that the burr hole cap fits snugly into the hole. In an occasional case where the burr hole had become bigger, bone dust along with bone cement has been used to secure the cap in position.

Erosion and infection are major complications reported in all series. The incidences range from 1 to 8.3% in large series. Infection should be aggressively addressed

and at the first sign of pus formation, the offending device should be explanted to save the more proximal parts, i.e. if IPG gets infected, removal of IPG may help to salvage extension; however, after frank pus formation it may be difficult to salvage the system. Once the infection occurs, the IPG should be explanted and fresh IPG should be reimplanted on the opposite side, as trying to sterilize the IPG may fail disastrously [26]. Patients who cannot maintain hygiene or care for themselves are at a much higher risk of infection as evidenced in 2 patients in this series with dystonia. If these 2 patients were excluded, the infection risk would be less than 2%. Another PD patient had his system explanted in the perioperative period due to infection at the connector site. The infection rate has been found to be greater in patients who had devices externalized for trial stimulation [26]. IPG implantation on the day after surgery ensuring better surgical environment, hospitalization till the time of suture removal, complete head shaving, C-shaped scalp incision, implantation of a low profile connector (Medtronic 7482) above the level of the ear, and attentive care of the wound even after suture removal are some of the steps that have resulted in a reduced infection rate.

IPG malfunction can occasionally occur. However, apart from identifying it, nothing can be done and replacement with a new IPG would be required. No lead fracture was encountered in the present series.

Systemic problems like urinary tract infection or respiratory infection are known to negate the effect of levodopa in patients with PD [27, 28]. However, a similar incidence rate following successful DBS has not been reported previously. It is, therefore, important to investigate the patient for any systemic infection whenever there is a sudden loss of response to DBS that cannot be explained by device malfunction.

One of the patients developed respiratory distress after the implantation of the lead on one side. He did not have any preoperative antecedent condition to predispose him to such complication. The procedure had to be abandoned to be finished at a later stage. In order to avoid recurrence of such a situation, the author advises the use of a CRW UCHR system, which provides the anesthetist airway access in times of emergency by detaching the front piece. PD patients sometimes have mild dystonic posturing of the neck. Extra care should be taken to make sure that the patient has an absolutely comfortable neck position by accommodating adjustments such as tilting the head sideways or providing support under the neck. Special attention should be paid to ensure that there is no undue flexion of the neck, which may result in breathing difficulty.

The jury is still out on the benefits of DBS in the elderly. Few studies have focused on comparing the complication rates between young and old patients [27–29]. They have concluded that the complication rate was similar in these two age groups. The author's own analysis revealed that the complication rate in the elderly was 17.5% and in the younger group it was 15% (Fisher's exact probability test $p = 0.6$, n.s.). Hence, it can be said that DBS is equally safe in elderly patients.

Conclusion

DBS is a relatively safe surgical procedure if performed by an experienced team. Adherence to a strict protocol by the entire team and attention to minute details help to reduce the surgical risks. Elderly patients have the same rate of complications as younger patients; however, there is an increased chance of postoperative confusion, which should be considered during the surgical planning and postoperative management.

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