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# Implantation of bilateral deep brain stimulators in patients with Parkinson disease and preexisting cardiac pacemakers

## Report of two cases

**PATRICK B. SENATUS, M.D., PH.D., SHEARWOOD MCCLELLAND III, A.B., ANJANETTE D. FERRIS, M.D., BLAIR FORD, M.D., F.R.C.P.(C), LINDA M. WINFIELD, R.N., M.P.H., SETH L. PULLMAN, M.D., F.R.C.P.(C), QIPING YU, PH.D., GUY M. MCKHANN II, M.D., STANLEY J. SCHNELLER, M.D., AND ROBERT R. GOODMAN, M.D., PH.D.**

*Departments of Neurological Surgery, Neurology, and Cardiology, Columbia College of Physicians and Surgeons, New York, New York*

✓ Deep brain stimulation (DBS) has become an important modality in the treatment of refractory Parkinson disease (PD). In patients with comorbid arrhythmias requiring cardiac pacemakers, DBS therapy is complicated by concerns over a possible electrical interaction between the devices (or with device programming) and the inability to use magnetic resonance imaging guidance for implantation. The authors report two cases of PD in which patients with preexisting cardiac pacemakers underwent successful implantation of bilateral DBS electrodes in the subthalamic nucleus (STN).

Each patient underwent computerized tomography–guided stereotactic frame–based placement of DBS electrodes with microelectrode recording. Both extension wires were passed from the right side of the head and neck (contralateral to the pacemaker) to place the cranial pulse generators subcutaneously in the left and right abdomen. The cranial pulse generators were placed farther than 6 in from the cardiac pacemaker and from each other to decrease the chance of interference between the devices during telemetry reprogramming.

Postoperative management involved brain stimulator programming sessions with simultaneous cardiological monitoring of pacemaker function and cardiac rhythm. No interference was noted at any time, and proper pacemaker function was maintained throughout the follow-up period. With bilateral STN stimulation, both patients experienced a dramatic improvement in their PD symptoms, including elimination of dyskinesias, reduction of "off" severity, and increase of "on" duration.

With some modifications of implantation strategy, two patients with cardiac pacemakers were successfully treated with bilateral DBS STN therapy for refractory PD. To our knowledge, this is the first report on patients with cardiac pacemakers undergoing brain stimulator implantation.

**KEY WORDS • deep brain stimulation • cardiac pacemaker • subthalamic nucleus • Parkinson disease**

DEEP brain stimulation of the STN significantly improves motor performance in patients with medically refractory PD.[1,5,7,10,19] In patients with PD and comorbid arrhythmias that require cardiac pacemakers, however, the DBS device presents certain considerations that may make practitioners reluctant to attempt implantation. The first consideration is the theoretical risk of electrical interference between the cardiac pacemaker and the brain stimulator current, as indicated in the "Precautions" segment of the Medtronic Activa deep brain stimulating electrode instruction manual: "The Activa System may affect the operation of other implanted devices, such as cardiac pacemakers and implantable defibrillators. Possible effects include sensing problems and inappropriate device responses." The second consideration is the inability to use MR imaging guidance (due to the presence of the pacemaker) for planning of implantation preoperatively and electrode localization postoperatively. A third consideration is that the location of the pacemaker may necessitate a modification of typical cranial pulse generator implantation. An alteration of the existing protocol for DBS implantation is required for these patients to provide them with the relief of PD symptoms that is provided by DBS.[10–13,17,18] We report on two patients with previously implanted pacemakers who underwent implantation of bilateral STN DBS devices for medically refractory PD.

*Abbreviations used in this paper:* CT = computerized tomography; DBS = deep brain stimulation; EKG = electrocardiography; ICD = implantable cardiac defibrillator; MER = microelectrode recording; MR = magnetic resonance; PD = Parkinson disease; STN = subthalamic nucleus.

### Patient Histories and Illustrative Case

*Patient Histories*

*Case 1.* Our first patient was a 71-year-old right-handed

man with a medical history of atrial fibrillation and bradycardia–tachycardia syndrome for which he received a dual-chamber atrial response bipolar pacemaker (Medtronic 701 pulse generator, two atrial leads, adapter for connecting two IS1 unipolar leads to an IS1 bipolar ventricular lead; Medtronic, Inc., Minneapolis, MN) in 1999. His PD first presented as left arm stiffness in 1987. Two years later a formal diagnosis of PD was made and the following year the patient began medical management with Sinemet (carbidopa–levodopa). He had experienced excellent PD symptom control with medical therapy for 5 years. He subsequently required escalating medication due to the "wearing-off" phenomenon, and his activities of daily living became severely compromised by peak dose dyskinesias and episodes of severe "off" times. He was referred by his neurologist for consideration of bilateral STN stimulation therapy.

*Case 2.* Our second patient was a 60-year-old right-handed woman with a medical history of Marfan syndrome, an aortic enlargement for which she had received a porcine aortic valve replacement and an aortic root replacement, and cardiac arrhythmias for which she had received a St. Jude dual-chamber permanent pacemaker (Identity XL DR model, an atrial lead, and a ventricular lead; St. Jude Medical, Inc., Minneapolis, MN) for an atrioventricular block in 2002. This patient's PD first presented as left hand tremor and left leg dragging in 1994, and she had been taking Sinemet since 1995. Her motor complications began in 1997, manifesting as dyskinesias and severe disabling "off" periods. Despite an initial response to medical management, she gradually experienced a decrease in quality of life because of her severe motor fluctuations. These occurred despite maximally tolerated medication, producing symptoms predominantly on her left side. The patient was referred by her neurologist for consideration of STN stimulation therapy for her medically refractory PD. Given the predominance of her left-sided symptoms, a unilateral right implantation was initially considered. After the development of significant right-sided symptoms, however, the recommendation was switched to bilateral STN implantation.

### *Preoperative Testing Session*

There was a theoretical risk of far-field sensing by the pacemaker of the DBS programming device, which potentially could result in pacemaker inhibition. Taking this risk into account each patient underwent a preoperative simulation involving neurosurgical, neurological, and cardiological monitoring. The details of the following session apply to our first patient, but a similar approach was also used for our second patient.

After baseline studies had been conducted, stimulation was initiated. During this simulation, a screener device (Test Stimulator model 3625; Medtronic, Inc.) was programmed to typical DBS parameters. Programming of the device was performed in the proximity of the patient to evaluate any interaction with his pacemaker. The screener device was used with alligator clip wires to supply stimulation to the skin over the patient's chest wall through the EKG electrode contacts. The EKG was used to monitor the patient as the stimulation was escalated to a maximum of 10 V with a pulse width of 120 μsec and a frequency of 185 Hz. Although this produced a very strong artifact in the EKG signals, it did not alter the patient's cardiac rhythm. A subsequent evaluation of the pacemaker demonstrated no apparent alteration in pacemaker function.

Following this, an Itrel II pulse generator, which was connected to an extension wire and a stimulating electrode lying on the patient's abdomen and chest wall, was programmed using the programming wand. The pulse generator itself was located in the lower quadrant of the patient's abdomen in the planned location for the implant. After the pulse generator was programmed, the patient's cardiac rhythm remained unchanged; the pacemaker was subsequently evaluated and no change in its parameters could be found. The stimulator was programmed to the same settings used for the screener device test. The patient tolerated this procedure well, indicating the likelihood that there would be no interference among the brain stimulator device, the patient's cardiac pacemaker, and/or the programming device. Both patients understood that we could not be certain that there would be no interference between the brain stimulator and pacemaker devices. They elected to proceed with implantation despite this known risk.

### *Electrode Implantation*

Only the procedure performed in Case 1 will be described. Implantation was performed after obtaining informed consent. A functional Cosman–Roberts-Wells stereotactic frame (CRW; Radionics, Inc., Burlington, MA) was secured to the patient's head. Axial CT scanning of the head was performed (2-mm contiguous slices) with a gantry angle of 0°, and the resulting images were transferred to the Stealth FrameLink 3.0 workstation (Medtronic, Inc.) for surgical planning.

The images were reformatted into the plane containing the anterior and posterior commissures and the program-calculated target points in the right and left STN (4 mm posterior, 4 mm inferior, and 12 mm lateral to the intercommissural midpoint and adjusted for the length of the anterior commissure–posterior commissure line). A trajectory was obtained for each target with an entry point in the region of the coronal suture at the crown of a gyrus that avoided penetration of the lateral ventricle or crossing of any deep sulcus. On the right side, MER was performed via a burr hole through the targeted area, along four parallel trajectories, to identify the boundaries of the STN.

From these results, a trajectory believed to reach the middle of the STN (1 mm anterior to the original target) was used for DBS electrode placement, advancing the tip 2.5 mm beyond the calculated target depth (Soletra generators and quadripolar electrodes; Medtronic, Inc.). A test stimulation produced typical paresthesias and improvements in the patient's bradykinesia and rigidity. The electrode was anchored to the skull and its proximal portion was placed in a subgaleal pocket.

A similar implantation was performed on the left side, where two MER passes were conducted to identify adequately the desired target for the stimulating electrode, which was placed at target coordinates that mirrored those on the other side. Postoperative CT scanning demonstrated the expected electrode positions and no intracranial bleeding. The patient's recovery was complicated by transient postoperative confusion and he was discharged home on postoperative Day 8. The procedure on our second patient was similar (although not complicated by postoperative

confusion) and she was discharged home 2 days after electrode implantation.

*Cranial Pulse Generator Implantation*

On postoperative Day 17, the patient underwent implantation of the cranial pulse generators (Soletra model 7426; Medtronic, Inc.). Following induction of general anesthesia and endotracheal intubation, the incisions made earlier at the coronal suture areas were reopened, the previously implanted left brain electrode was passed over to the right wound, by using a subgaleal tunnel, and the left wound was closed. Horizontal incisions were made in each lower quadrant of the abdomen to create subcutaneous pockets inferior to each incision. An extension wire (Medtronic, Inc.) was passed from the left to the right wound. Pulse generators were placed in each pocket and the two extension wires were passed from the right wound to an incision behind the right ear. Two parallel troughs were drilled in the outer table of the skull to allow countersinking of the electrode connectors. The extension wires were connected to the DBS electrodes and positioned in the troughs. The cranial pulse generators were placed farther than 6 in away from the cardiac pacemaker and from each other to decrease the chance of interference between the devices during telemetry reprogramming.

*Postoperative Course*

The patient made a full postoperative recovery after his initial postoperative agitated confusion and was discharged home on postoperative Day 5. Our second patient underwent a similar cranial pulse generator implantation as an ambulatory procedure.

Beginning 1 month postoperatively, our first patient was seen regularly for brain stimulator programming sessions with simultaneous cardiac monitoring. The Medtronic stimulator programmer was used to analyze and reprogram the stimulators and simultaneous cardiological monitoring of the patient's cardiac pacemaker and EKG was conducted by a member of the team (S.J.S.). A variety of electrode combinations (limited to the bipolar setting to reduce potential interaction with the pacemaker), pulse widths, frequencies, and amplitudes were tested with the patient in the "on" state. Settings were found for each electrode that produced strong transient paresthesias, no undesirable effects, and no alteration in the patient's baseline motor function. Comprehensive cardiological monitoring and evaluation of the pacemaker, including EKG monitoring, magnet testing, pacemaker interrogation using the programmer, review of telemetry, lead impedance, battery status, temporary reprogramming for troubleshooting, and threshold testing, revealed normal function of the pacemaker with no evidence of interaction between the electrodes and the pacemaker. The final settings for the left electrode were the following: amplitude 2.6 V, pulse width 60 μsec, rate 145 Hz, Electrode 1 negative, and Electrodes 0 and 2 positive with a soft start. For the right electrode, the final settings were the following: amplitude 3.3 V, pulse width 60 μsec, rate 145 Hz, Electrode 1 negative, and Electrodes 0 and 2 positive with a soft start. Subsequent postoperative sessions 1, 3, 18, and 22 months later revealed the continued absence of any interaction between the DBS electrodes and the pacemaker. The patient experienced significant improvement in his preoperative PD symptoms with markedly reduced dyskinesias, improvement in rigidity, markedly reduced severity of "off" time, increased "on" duration, and reduction in his antiparkinsonian medication requirement.

For both patients, after several sessions confirmed the lack of interference between brain stimulator programming and the cardiac pacemaker function, the cardiologist believed that future brain stimulator programming could be done safely without cardiological monitoring. Our second patient had a postoperative course similar to that of the first patient, and obtained excellent clinical benefit with monopolar settings (final settings for the right electrode: amplitude 3.5 V, pulse width 60 μsec, rate 185 Hz, Case positive, and Electrode 2 negative; final settings for the left electrode: amplitude 2.5 V, pulse width 60 μsec, rate 185 Hz, Case positive, and Electrode 1 negative) 4 months postoperatively, although she is no longer able to undergo transtelephonic monitoring unless she turns off her brain stimulator devices.

## Discussion

Cardiac pacemakers have been successfully implanted with a variety of preexisting electrical devices, including spinal cord stimulators,[9] implantable cardiac defibrillators,[2,3] and bilateral thalamic ventral intermediate nucleus DBS electrodes.[6] The authors are unaware of any published report describing the implantation of a brain stimulator in a patient with a preexisting cardiac pacemaker. Problems involving interactions between a pacemaker and an implanted electrical device have primarily manifested as an inhibition or suppression of pacing, which has resulted in rhythm disturbances, myocardial burns, and cardiac arrest.[4,17,21] Similarly, ICDs have been successfully implanted in patients with preexisting electrical devices, such as cochlear implants[8] and spinal cord stimulators.[14] The largest attendant problem appears to be inappropriate shock due to electrical interference.[20]

Of note, ICDs have also been successfully implanted in patients with preexisting DBS electrodes in the thalamus and the STN[16,22] without adverse effects. In a separate report on a patient with an ICD and bilateral STN stimulators, stimulation of the DBS electrodes had no effect on the ICD.[26] Nevertheless, there have been reports of ICD discharge at the time of implantation resulting in changes in the DBS generator settings (resetting of generator output to "off" with an amplitude of 0 V), which were manifested as alterations in the following parameters: amplitude limit, pulse rate, upper and lower rate limits, and the electrode configuration.[26] In another report, a patient with implanted STN electrodes experienced microwave diathermy near the path of the DBS lead, which led to permanent diencephalic and brainstem lesions that were concomitant with a vegetative state.[15] A third report of a patient with an implanted DBS who underwent postimplantation cardioversion also revealed an adverse outcome.[28] According to that report, the patient underwent implantation of a thalamic stimulator, a radiofrequency-coupled system that included an external pulse generator and transmitter. Unfortunately, the subcutaneous radiofrequency receiver transmitted the external cardioversion current, resulting in two adverse events: a thalamotomy and central pain due to the spread of the current to the ventrocaudal nucleus.

Given such reports of undesirable electrical interaction–induced outcomes in patients with implanted DBS devices, practitioners may be reluctant to recommend patients with preexisting pacemakers and medically refractory PD for DBS implantation. Compounding matters include two special considerations that must be accounted for: the inability to use MR imaging guidance in the procedure and the requirement for a site of cranial pulse generator placement other than the usual infraclavicular location because of the position of the preexisting pacemaker.

Modifications in the usual DBS implantation procedure[24,25,27] allowed successful bilateral STN DBS implantation in our two patients. Computerized tomography guidance was used in place of typical MR imaging guidance. Final placement was guided by MER recording, similar to routine implantation procedures.[23,24] Both DBS electrodes were passed on the right side of the head and long extension wires permitted placement of the pulse generators in the right and left abdomen (each farther than 6 in away from the cardiac pacemaker). Bipolar and monopolar programming modes were used effectively and safely in both patients. In both, the initial programming sessions were attended by cardiological monitoring, but subsequent brain stimulator programming was routinely carried out without this monitoring. Of note, these two patients had different types of cardiac pacemakers. For our second patient, transtelephonic monitoring requires that she turn off her brain stimulators. This is a relatively minor inconvenience. Although it is likely that our experience can be successfully extrapolated to patients with various cardiac pacemaker models, it may be advisable in future patients to perform similar pacemaker monitoring during early brain stimulator programming sessions.

The pacemakers reported here were "demand" pacemakers, typical of the vast majority of pacemakers implanted in the present era. Both devices were bipolar devices, in which the dipole used for sensing was within the heart, as opposed to unipolar devices in which the dipole is between the heart and the pacemaker generator in the chest. In a unipolar device, the metal encapsulating the pacemaker in the chest participates in the sensing circuit (electrically active), whereas in a bipolar device, metal in the chest is excluded from the sensing circuit because that circuit is composed of the dipole on each lead in the heart (the anode and cathode are on the lead itself). The vast majority of pacemakers implanted presently are bipolar in configuration. We suspect that bipolar devices are less likely to sense stimuli from DBS electrodes than unipolar devices. Our experience to date has been limited to bipolar devices and may not be applicable to unipolar devices. If the implanted pacemaker lead is bipolar, the pacemaker can be programmed to act as a bipolar or unipolar device. The limitation would be that if the lead is unipolar, bipolar programming would not be feasible, even if the device can be programmed to the bipolar configuration. Because bipolar leads permit bipolar device programming and because the bipolar configuration is less susceptible to oversensing, we believe that bipolar leads are preferable in all cases. The bipolar configuration is less likely to sense extraneous signals because sensing occurs within the heart rather than between the heart and chest wall. Based on our pacemaker experience, which showed that oversensing is less likely to occur in the bipolar configuration, a bipolar configuration of the lead and generator program is preferable and advisable in general, and may be one reason we did not encounter problems in either of our patients. There may be more reasons to be concerned about the unipolar configuration sensing the DBS pulse, but this has yet to be tested. In patients such as ours, it is important for the treating cardiologist to maintain bipolar programming. If one believes that unipolar programming is required, testing should be performed to rule out oversensing induced by the brain stimulators.

In conclusion, our experience with the first two reported cases of successful DBS implantation in patients with previously implanted cardiac pacemakers will hopefully allay the concerns of cardiologists, neurologists, and neurosurgeons about the application of DBS therapy in suitable candidates with preexisting cardiac pacemakers. Our experience to date is limited, however, and we recommend preoperative testing with cardiological monitoring in the application of DBS therapy for this patient population.

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*Address reprint requests to:* Robert R. Goodman, M.D., Ph.D., Department of Neurological Surgery, Neurological Institute of New York, Columbia College of Physicians and Surgeons, 710 West 168th Street, Box 99, New York, New York 10032. email: rrg2@columbia.edu.