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Technical Note

The importance of testing deep brain stimulation lead impedances before final lead implantation

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Abstract

Background: In the setting of a deep brain stimulation (DBS) lead with defective electrical circuitry, potential patient morbidity and additional surgery may be avoided if impedance testing of the brain lead is performed prior to final lead implantation. In the present report, detection of a short circuit upon lead placement and prior to lead anchoring was detected utilizing recently released DBS hardware and software (Medtronic, Minneapolis, MN). This report suggests that neurosurgeons need to be aware and consider the use of the newly available DBS testing equipment.

Methods: During the first DBS lead placement in a 69-year-old man with advanced idiopathic Parkinson's disease undergoing bilateral subthalamic nucleus DBS over staged procedures, test stimulation and lead impedance testing were accomplished prior to lead anchoring. An external neurostimulator (ENS) was affixed to an updated clinician programmer and connected to the DBS lead with a screening cable specific for the ENS and DBS.

Results: Impedance testing demonstrated a short circuit involving the 1 and 3 lead-electrode bipolar combination in a visually intact lead. The lead was replaced, repeat impedance testing and test stimulation were completed and the intact lead was secured. Subsequent DBS surgeries were completed uneventfully. The lead abnormality was verified by the manufacturer.

Conclusions: This case highlights a new method to test DBS lead circuitry at the time of placement. The method may also be employed to directly test lead integrity when localizing a DBS system short or open circuit of unclear etiology. Our case suggests that the method is valuable and should be utilized.

Key Words: Complication avoidance, deep brain stimulation, external neurostimulator, impedance testing, intraoperative test stimulation

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INTRODUCTION

Until recently, it has not been possible to test the impedances and thus the integrity of a deep brain stimulation (DBS) lead until the lead was connected via extension wire to an implanted DBS pulse generator (IPG). DBS system implantations are often staged, with implantation and connection of the extension wire and IPG to the brain lead completed at a later date following lead implantation. Should a short or open circuit be

detected upon extension wire and IPG implantation, the specific DBS hardware causing the abnormal readings often can only be isolated via trial and error, which usually entails directly checking the extension wire connections to the IPG and then the lead. This may result in extension wire replacement and if this fails, ultimately lead replacement. Further, if a short or open circuit is localized to the lead, it is generally assumed that the lead was damaged during surgery.

Recently, hardware and software for measuring DBS lead impedances was released allowing the ability to check the integrity of a brain lead at the time of lead placement, prior to and independent of IPG implantation. In the present case, we report the detection of a short circuit involving a DBS lead at the time of lead implantation with the stereotactic frame in place, prior to final lead anchoring. Prior to testing the lead impedances, abnormality involving the lead was not suspected. This case highlights the availability and importance of testing lead circuitry at the time of lead placement and suggests that such testing should initially be performed prior to separating the lead and associated guide tube from the stereotactic apparatus. The method can be repeated following securing the lead if questions regarding lead integrity arise during lead anchoring or subsequently. The lead could also be checked prior to starting surgery.

MATERIALS AND METHODS

The patient was a 69-year-old male with a 15-year history of idiopathic Parkinson's disease undergoing bilateral subthalamic nucleus (STN) DBS and satisfying inclusion and exclusion criteria for the surgery.[3,4,6] Our surgical method to accomplish bilateral STN DBS over staged procedures has been described previously.[2,6,7] In the present case, on the morning of the first lead implantation, 1.5 T magnetic resonance imaging (MRI) brain scanning (Signa Excite HDx, General Electric Medical Systems, Milwaukee, WI) was performed for direct target purposes, following placement of a stereotactic frame (MRIA-UHRA, Integra Radionics, Burlington, MA). A paraventricular approach was planned (NeuroSight Arc 2.5, Integra Radionics) avoiding sulci and vessels and using a gyrus close to the inner skull bone for brain entry. Single pass microelectrode (mTSWAN JN/JN1, FHC, Bowdoin, ME) recordings (Leadpoint, Medtronic, Minneapolis, MN) were utilized to localize somatosensory STN for DBS lead (model 3389, Medtronic) implantation. Following microelectrode localization, the microelectrode was withdrawn and the brain guide cannula was advanced to the defined target point. The DBS lead within the microTargeting Drive DBS Lead Holder (model 66-CN-D8, FHC) affixed to the stereotactic frame was advanced with a motorized microdrive (model 66-DS-PA, FHC). The guide tube was then retracted to expose the lead-electrodes.

Test stimulation followed by a check of lead-electrode impedances was accomplished using a clinician programmer (model 8840, Medtronic) and the recently available DBS external neurostimulator (ENS) (model 37022, Medtronic) affixed to the programming head of the clinician programmer [Figure 1]. The clinician programmer was updated with a software application card (model 8870 version AAO (8870AAO), Medtronic) applicable to the ENS. The 8870AAO software card also permits programming with the 8840 clinician programmer for all current DBS pulse generators (models 7726 (Soletra), 7728 (Kinetra), 37602, 37603 (SC), 37601 (PC), and 37612 (RC)). The 37022 ENS is required for intraoperative test stimulation and impedance testing of DBS leads using the 8840 clinician programmer. The ENS was connected to the DBS lead with a twist-lock screening cable (model 3550-68, Medtronic), specific for the ENS and DBS [Figure 1]. Test stimulation was conducted in a progressive fashion to ensure benefit within a clinically desirable stimulation range and no side effects to 6 V at a pulse width of 90 microseconds and a frequency of 180 Hz using electrodes 0 and 3 for bipolar stimulation. A check of lead-electrode impedances was then performed with the already attached programmer and ENS. This method tests impedances using bipolar parameters at stimulation amplitudes of 0.7 V, 1.5 V, and 3.0 V, with pulse width (80 microseconds) and rate (100 Hz) preset by the manufacturer. Most commonly, impedance assessment is conducted at the lowest amplitude necessary for successful DBS lead impedance

Figure 1: Front (left) and back (right) views of clinician programmer (model 8840, Medtronic, Minneapolis, MN) with external neurostimulator (model 37022, Medtronic) attached to the back of the programmer. The programmer has been updated (model 8870 version AAO Application Card, Medtronic). Also shown is the deep brain stimulation specific external neurostimulator twist-lock screening cable (model 3550-68, Medtronic) which connects the external neurostimulator to a deep brain stimulation lead. In addition to intraoperative test stimulation using the programmer, the system makes possible check of impedances specific to the deep brain stimulation lead and thus the integrity of the lead. Deep brain stimulation specific external neurostimulator screening cable with alligator clips (not shown) rather than twist-lock may be used.

testing. A short circuit is suspected with an impedance value of less than 250 Ω while upon bipolar stimulation an impedance greater than 4000 Ω suggests an open circuit.[5]

RESULTS

Upon impedance testing at 0.7 V, readings consistent with a short circuit (<50 Ω) involving the number 1 and number 3 lead-electrode bipolar combination were encountered. Impedances involving the other lead-electrode bipolar combinations were within normal limits. The impedance testing was repeated at 1.5 V and again readings consistent with a short circuit involving bipolar stimulation of the lead-electrode 1 and 3 combination were encountered. Repeat testing at 3 V gave the same results. The lead was removed and the guide tube with guide stylet in place was advanced the distance that it had earlier been retracted following which a new lead was placed. Impedance testing of the new lead at 0.7 V, 1.5 V, and 3.0 V demonstrated all impedances of the new lead to be within normal limits. Test stimulation using electrodes 0 and 3 of the new DBS lead again demonstrated beneficial effects within clinical desirable stimulation range and without side effects upon testing to 6 V. The lead was secured and remaining planned staged procedures to accomplish bilateral STN DBS were accomplished without incident.

After completion of the case involving the lead in question, the removed lead was tested using 0.9% saline bath to submerge the lead-electrodes and using the clinician programmer, ENS, and twist-lock cable used as during the surgery together with short lead stylet, the latter packaged with DBS leads and also the new connection cables. Upon bench testing, a short circuit (< 50 Ω) involving the lead- electrode 1 and 3 bipolar combination was again encountered at all test voltages (0.7 V, 1.5 V, and 3.0 V). A defect or breakage either in the outer polyurethane coating, conductor wires, proximal connector, or stimulating electrodes comprising the lead was not appreciated to visual inspection with 2.5 x loupe magnification. The lead was returned to the manufacturer for analysis. The manufacturer reported, "… A low impedance measurement was observed on electrode pairs 1 and 3 (<50 Ω), indicating a short circuit. Visual analysis noted that the distal end of the lead was stretched and the outer insulation of the lead was broken between the electrode sleeves. Analysis confirmed an electrical short circuit at the proximal end of the lead, near the #1 connector sleeve."

DISCUSSION

Until very recently, intraoperative clinical test stimulation required using model 3625 Test Stimulator (Medtronic) connected to the DBS lead via alligator clip- or twist-lock screening cable provided with the DBS lead. However, testing of DBS lead impedances was not possible at the time of test stimulation using the 3625 stimulator. The only way to ensure the integrity of a DBS lead was after the lead had been connected to an IPG by way of telemetry using the clinician programmer (model 8840, Medtronic). However, the IPG needed to be located within body soft tissues. If during impedance testing the lead is connected to an externalized IPG, impedance readings of open circuits for both monopolar and bipolar parameters are obtained for all lead-electrodes.

In staged procedures, implantation of the IPG together with the extension wire and connection to the already implanted lead occurs as a separate operation most usually one to two weeks after lead implantation, possibly longer. Discovery of a lead circuitry problem in such a setting requires, dependent on surgical method, one if not more additional surgeries for lead replacement. Even in a surgery in which lead, extension wire, and IPG are planned as a single procedure, discovery of a lead circuitry problem upon connection to the IPG would complicate the procedure and in many instances would also require separate surgery to correct the hardware problem.

Recently released hardware and software makes possible the intraoperative testing of impedances of DBS leads (3387 and 3389) at time of lead placement and independent of IPG implantation. The 8870AAO Application Card is loaded to the 8840 clinician programmer making possible communication between the programmer and the 37022 ENS. For intraoperative testing, the ENS is attached to the programmer within a slot in the programmer head, which in turn is connected to the lead via alligator clip (model 3550-67, Medtronic) or twist-lock screening cable (model 3550-68, Medtronic) specific for the ENS and DBS. As specified by the manufacturer, orientation of the ENS in relation to the programmer should be as depicted in Figure 1 and caution must be exercised as we have found that reverse orientation of the ENS (ENS rotated 180°) in relation to the programmer is possible. The ENS alligator clip and twist-lock cables are each separately packaged and are not included with the 3387 or 3389 DBS leads. The alligator clip and twist-lock cables currently included with these leads are for connection to the model 3625 Test Stimulator. Other external stimulators, such as the DualStim screener (model 3728, Medtronic), have been utilized for DBS applications.[8] However, the Dual-Stim stimulator is labeled only for pain applications and impedance testing of solely the lead is not possible. If the stylet handle and straight stylet have been removed from the lead, the short stylet (and handle) currently provided with the 3387 and 3389 DBS leads and also with the new screening cables should be used with the twist-lock connection cable and may be used with alligator

clip cable. The method may also be utilized to check the impedances of an externalized DBS lead and might employ use of the percutaneous extender (model 3550-05, Medtronic). It is worthy to note that the 37022 ENS had prior been labeled for only non-brain pain-related procedures and utilized connector cables different than those referenced in this report. Further, the ENS and associated DBS connector cables are presently labeled only for use with the 3387 and 3389 DBS leads and not for the 3391 model lead; the 3391 lead is labeled for DBS in medication refractory severe obsessive compulsive disorder patients.

In the present report, a defective lead was detected following insertion into brain though prior to removal of the lead's straight stylet and while the guide cannula was in place within the stereotactic frame. Until very recently, localization of such a problem to the lead was possible only by inference and following elimination of possible problems elsewhere in a complete DBS system. Etiology of why the lead was defective in our case is not clear and a lead problem was not suspected until impedance test results were obtained. The lead was handled only by the lead surgeon (JMN). The defects referable to the lead upon the DBS manufacturer's analysis are very unlikely to be secondary to over tightening of the FHC lead holder screw as this is not permitted by the FHC hardware design. In addition, our lead holder was not part of a recent FDA recall (Z-0311-2011) specific to this problem of lead damage related to the lead holder, and the locations of the lead defects do not correlate with the FHC securing screw location in reference to the lead.

While we tested the lead following test stimulation, a DBS lead may be tested prior to brain insertion by submerging the lead-electrodes in 0.9% saline and using the ENS and twist-lock screening cable together with an updated (8870AAO Application Card) 8840 clinician programmer. However, this may increase the risk of infection and currently is not our standard method. The lead may also be tested following insertion within brain and after removal of the straight (long) stylet from within the lead with proper use of the DBS ENS alligator clip or twist-lock screening cables, depending on surgeon preference. The later method may prove useful if there is question of lead integrity after securing the lead to the skull or should plain radiographs[1] or radio transmission[1] not localize the hardware area responsible for a short or open circuit encountered at a later date.

CONCLUSION

Recently released hardware and software make it possible to check DBS lead electrical integrity at the time of lead placement. It may also be employed when attempting to isolate the hardware responsible for a new short or open circuit in an already implanted and otherwise intact DBS system. Our case suggests that the method is valuable and should be considered as it may reduce additional surgeries related to a faulty lead.

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