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Frameless Stereotactic Robot-Assisted Subthalamic Nucleus Deep Brain Stimulation: Case Report

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Key words

- Deep brain stimulation
- Frameless
- Robot stereotactic assistance
- ROSA

Abbreviations and Acronyms

CT: Computed tomography
DBS: Deep brain stimulation
FDA: Food and Drug Administration
MER: Microelectrode recording
MRI: Magnetic resonance imaging
STN: Subthalamic nucleus

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INTRODUCTION

Deep-brain stimulation (DBS) is used to treat a variety of diseases and symptoms, including essential tremor, dystonia, Tourette syndrome, and Parkinson disease.¹ Bilateral DBS of the subthalamic nuclei (STN) in patients with Parkinson disease is associated with improvement of motor function and low rates of complications.²⁻⁴ DBS is considered in Parkinson disease when patients respond to levodopa, but the duration of benefit is too short or there are too many undesired complications.¹

DBS electrode implantation can be achieved in a variety of ways, with the 2 main categories including frameless and frame-based systems. Currently, frame-based systems are considered to be the “gold standard” because they are precise, reliable, and have been used for many years with good results.⁵ Frame-based systems can be relatively accurate,

■ **BACKGROUND:** Electrode implantation for deep brain stimulation (DBS) can be performed in numerous ways, but the current “gold standard” is the use of frame-based systems for accuracy. Robotic stereotactic procedures, however, have gained increased interest because of their ease of use and reliability, but there could be concern about their safety in the United States as the result of recent lawsuits (e.g., the da Vinci Surgical System). We report the first DBS implantation performed using a robot (ROSA robotic device) approved by Food and Drug Administration for use in North America.

■ **CASE DESCRIPTION:** A 56-year-old, right-handed woman with a 12-year history of Parkinson disease is described. She was offered bilateral subthalamic nucleus DBS placement to address motor fluctuations and dyskinesias. DBS electrode implantation was implemented successfully with ROSA robotic stereotactic assistance. Using preoperative magnetic resonance imaging scan acquisitions, we targeted the patient’s subthalamic nucleus bilaterally. Bone fiducials were placed and intraoperative computed tomography (CT) imaging was obtained. The magnetic resonance imaging and CT were fused, and the patient was registered to the ROSA software. Trajectories were obtained and a microdrive device was fixed to the robotic arm to advance the electrode to the correct location. Electrodes were then placed bilaterally. Intraoperative CT showed good placement with no complications encountered.

■ **CONCLUSIONS:** The advantages of robotic assistance in stereotactic procedures are as follows: 1) improved accuracy, 2) “arc-less” approach, and 3) minor adjustments can be made in multiple planes to the entry point without adjustment of a frame. The case demonstrates robotic stereotactic assistance viability as an alternative to traditional frame-based or frameless systems in U.S. hospitals.

although submillimeter accuracy can be difficult to attain.⁶ Ultimately, accuracy and precision are considered to be the most crucial components of DBS electrode implantation.¹

Robot-assisted stereotactic techniques are a novel way of implanting DBS electrodes that have gained popularity in Europe recently⁷ but have not yet been well adopted in North America. We are aware of the Mazor robot (SpineAssist; Mazor Robotics, Caesarea Park South, Israel) that has been used in DBS implantation, but this robot currently is only approved by the Food and Drug Administration (FDA) for use in the spine.⁸ Frame-based robotic registration

has been performed and shown to have good accuracy, dexterity, and precision.⁷ Frameless stereotactic robot assistance has been used in DBS and provided accuracy that is comparable with the traditional manual systems.⁹ The ROSA robot (Medtech Surgical, Inc, Montpellier, France) has been used to place single or numerous electrodes into brain targets for stereoelectroencephalography and laser ablations for several years with good results.^{10,11} We report the first implantation of electrodes with a robot approved by the FDA for intracranial use for bilateral STN DBS in a patient with Parkinson disease in North America.

CASE REPORT

Presentation

A 56-year-old, right-handed woman with a 12-year history of Parkinson disease is described. Despite optimization of medical therapy by a movement disorders neurologist, she experienced disabling rigidity and bradykinesia with a waning of medication efficacy and medication-associated dyskinesias during the “on” state. Treatment options were presented to her, and she agreed to DBS.

Treatment

The patient was treated with bilateral DBS electrode implantation to the STN by the use of ROSA robotic stereotactic assistance. The ROSA robot consists of 1) a robotic arm that can position an electrode and 2) a computer screen displaying advanced imaging with proposed probe trajectory and depth (Figure 1).⁷ Using preoperative magnetic resonance imaging (MRI) scan acquisitions, we targeted the patient's STN. The procedure was performed with the patient under general anesthesia. She was placed in a Leksell headframe and fixed to the robot (the headframe was used only to hold

the patient's head in place and not for any stereotactic coordinate registration). Five bone fiducials were positioned in the patient's skull, and intraoperative computed tomography (CT) imaging was obtained with the BodyTom (NeuroLogica Corporation, Danvers, Massachusetts, USA) (Figure 1A). The images were loaded to the ROSA robot and the MRI and CT were fused. Registration was performed by contacting a pointer probe mounted to the robotic arm to each bone fiducial (Figure 1B).

Using the laser guide, we marked the entry points on the scalp and then the patient's scalp was cleaned and drapes were placed. Incisions were placed appropriately and the burr holes were placed at the predetermined locations. The robot calculated the appropriate trajectory and distance-to-target and positioned the arm to the appropriate location and angle (Figure 2A and C). We attached a microdriver device to the robotic arm, which was used to pass the electrode to the correct location.

During initial implantation of the left STN electrode, it was noted that the electrode was abutting the edge of the burr hole and so the robotic arm was

repositioned by the use of 1-millimeter adjustments to the entry point while maintaining the same target point. The “isocenter” function of the robot was used to perform this. This functional allows for millimeter movements of the entry point in multidimensional planes while maintaining the target. The procedure was repeated on the right side without any complication. Microelectrode recording (MER) was performed by a neurophysiologist during implantation on both sides and was noted to be in satisfactory position. MER was the surgeon's technique of choice of ensuring that the depth electrodes were placed in the correct location based upon audio feedback, because MER has been shown to be effective even under general anesthesia.¹² A subsequent intraoperative CT scan showed good positioning of the electrodes with no acute complications. Figure 2B shows the right electrode with an accuracy of 1.68 mm, whereas Figure 2D shows the left electrode with an accuracy of 1.14 mm. Three-dimensional error was calculated.

Postoperative Course

The patient tolerated the procedure well, and no complications were noted. She returned 2 weeks later for Stage-2 generator implantation and tolerated this well. Stimulation programming was accomplished without difficulty using monopolar settings. She noted improvement in her symptoms since implantation.

DISCUSSION

The use of a robotic assistance device for stereotactic procedures is becoming more commonplace for implantation of stereoelectroencephalography electrodes and laser ablation procedures.⁷ There are several benefits to robot-assisted stereotactic surgery: 1) improved accuracy compared with traditional stereotactic methods; 2) an arc-less approach; 3) incorporation of registration and navigation into one system; and 4) minor adjustments can be made to the entry point in multidimensional planes (as opposed to singular plane adjustments made with traditional methods) without readjusting the entire frame and while maintaining the same target point (maintenance of the “isocenter”). Although DBS has been performed in Europe using the ROSA

Figure 1. (A) Patient in Leksell head frame with robot above her head. (B) Close-up of ROSA robotic arm pointer probe registering bone fiducials screwed into the patient's head. (C) Photo of the ROSA robot arm. (D) Photo of the ROSA robot computer screen used by the surgeon.

Figure 2. (A) Location and angle of the electrode before placement into the right subthalamic nuclei (STN). (B) Actual placement of the electrode with an accuracy of 1.68 mm. (C) Location and angle of the electrode before placement into the left STN. (D) Actual placement of the electrode with an accuracy of 1.14 mm.

robot,⁷ to our knowledge, this is the first instance that robotic stereotactic assistance using a robot approved by the FDA for intracranial use in the placement of DBS electrodes in North America.

The use of a robot for assistance with implantation does require some alterations to the workflow for DBS implantation. For instance, the use of skull fiducials was required to ensure that the accuracy of the system was optimized. Although not usually part of the workflow, bone fiducial registration is a requirement for DBS implantation with the ROSA, which likely allows for improved accuracy over laser-guided surface registration that is routinely performed for other stereotactic procedures using robotic assistance. This added additional time to the procedure and required another CT scan to fuse with the MRI. Also, because the robot must remain fixed at the head of the patient, the operating room layout had to be adjusted (Figure 1). Finally, although the robotic arm has minimal motion once it has reached the trajectory, the

attachment between the microdriver device and the robotic arm did add a small amount of additional movement to the system.

Nevertheless, the robot offered several improvements over frameless and frame-based systems. Because the trajectories and distances were all calculated by the robot without human intervention, this removes any possibility of human error from calculation errors or translational errors. It also allows for better consistency. This system does not require a standard arc and frame for stereotactic coordinates while offering excellent accuracy and precision (Figure 2B and D). This system performs patient registration and navigation together, which likely offers increased efficiency over other frameless systems where this is performed separately. Finally, one of the main benefits of this system is that alterations can be made in the target and entry point with one-millimeter increments within multidimensional planes easily. When performing similar alterations with a frame-based system, this is often

time-consuming and onerous because adjustments need to be made to several coordinates to make small changes.

In the United States, there is concern that the push behind the current trend of using robot assistance in a wide number of procedures is based heavily on advertising with little evidence of actual benefit.¹³ The concern is further compounded by the fact that the FDA tightly regulates control over new drugs but exerts less control over new surgical techniques and tools, such as robot assistance.¹⁰ Indeed, recent lawsuits against Intuitive, the company that produces and distributes the da Vinci Surgical System,¹⁴ could be preventing U.S. hospitals and surgeons from pursuing robotic assistances more aggressively. Specifically, neurosurgery is considered one of the top malpractice risks,¹⁵ which may further dissuade U.S. neurosurgeons from taking risks and pursuing new methodology.

In presenting this case, we aim to show that our use of the ROSA robot is not the product of advertisement or any other unsubstantial claim, but instead a tool that could potentially give surgeons advantages over traditional manual methods in accurately implanting depth electrodes for DBS while ensuring the patient's safety.

The use of robotic stereotactic navigation systems such as the ROSA robot for DBS and other stereotactic procedures has significantly improved the ease of implantation, accuracy, and reliability of these procedures. As this technology continues to improve and more neurosurgeons become comfortable with these systems, robotic assistance will likely become more widely used for implantation of all types of stereotactic procedures.

CONCLUSION

This case provides the first use of ROSA robotic stereotactic assistance in placing bilateral DBS electrodes in the United States, demonstrating its viability as an alternative to traditional manual frame-based or frameless systems in U.S. hospitals.

REFERENCES

1. Perlmutter JS, Mink JW. Deep brain stimulation. *Annu Rev Neurosci.* 2006;29:229-257.
2. Beric A, Kelly PJ, Rezai A, Sterio D, Mogilner A, Zonenshayn M, et al. Complications of deep brain stimulation surgery. *Stereotact Funct Neurosurg.* 2001; 77:73-78.
3. Deep-Brain Stimulation for Parkinson's Disease Study Group. Deep-brain stimulation of the subthalamic nucleus or the pars interna of the globus pallidus in Parkinson's disease. *N Engl J Med.* 2001; 345:956-963.
4. Deuschl G, Schade-Brittinger C, Krack P, Volkmann J, Schäfer H, Bötzel K, et al. A randomized trial of deep-brain stimulation for Parkinson's disease. *N Engl J Med.* 2006;355: 896-908.
5. Hemm S, Wardell K. Stereotactic implantation of deep brain stimulation electrodes: a review of technical systems, methods and emerging tools. *Med Biol Eng Comput.* 2010;48:611-624.
6. Fiegele T, Feuchtnner G, Sohm F, Bauer R, Anton JV, Gotwald T, et al. Accuracy of stereotactic electrode placement in deep brain stimulation by intraoperative computed topography. *Parkinsonism Relat Disord.* 2008;14:595-599.
7. LeFranc M, Gars DL. Robotic implantation of deep brain stimulation leads, assisted by intraoperative, flat-panel CT. *Acta Neurochir.* 2012;154: 2069-2074.
8. Devito DP, Kaplan L, Dietl R, Pfeifer M, Horne D, Silberstein B, et al. Clinical acceptance and accuracy assessment of spinal implants guided with SpineAssist surgical robot: retrospective study. *Spine.* 2010;35:2109-2115.
9. Varma TRK, Eldridge P. Use of the NeuroMate stereotactic robot in a frameless mode for functional neurosurgery. *Int J Med Robot Comp.* 2006;2: 107-113.
10. Gonzalez-Martinez J, Vadera S, Mullin J, Enatsu R, Alexopoulos AV, Patwardhan R, et al. Robot-assisted stereotactic laser ablation in medically intractable epilepsy: operative technique. *Neurosurgery.* 2014;10:167-173.
11. Serletis D, Bulacio J, Bingaman W, Najm I, Gonzalez-Martinez J. The stereotactic approach for mapping epileptic networks: a prospective study of 200 patients. *J Neurosurg.* 2014;121:1239-1246.
12. Chkrabarti R, Ghazanwy M, Tewari A. Anesthetic challenges for deep brain stimulation: a systematic approach. *North Am J Med Sci.* 2014;6:359-369.
13. Pradarelli JC, Campbell DA, Dimick JB. Hospital credentialing and privileging of surgeons: a potential safety blind spot. *J Am Med Assoc.* 2015; 313:1313-1314.
14. Guthrie P. Robotic surgical system under scrutiny. *CMAJ.* 2014;186:22.
15. Chi JH. Neurosurgery tops malpractice risk. *Neurosurgery.* 2011;69:N18-N20.

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