Stereotactic Accuracy and Surgical Utility of the O-arm in DBS Surgery

Jonathan Dennis Carlson MD, PhD; Katie McLeod BA; Pamela PA McLeod
Inland Neurosurgery and Spine Associates
Providence Spokane Neuroscience Instititue
Spokane, WA

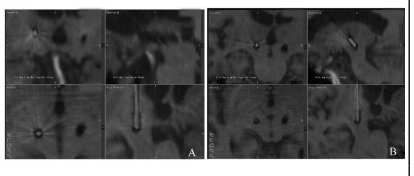
Introduction

The development of intraoperative imaging such as MRI, CT, and O-arm in deep brain stimulation has led to "asleep" surgery. The accuracy of these imaging techniques is critical when neurophysiological methods are bypassed.

There remains uncertainty as to the accuracy of the O-arm at predicting DBS electrode positions. There also is debate about the necessity of microelectrode recording when intraoperative imaging is used.

The objective of this study was to measure the accuracy of the O-arm, and to evaluate the utility of microelectrode recording when intraoperative imaging is used in an "awake" protocol.

O-arm fused to CT and MRI



(A) Intraop O-arm blended with postop MRI (B) Postop CT blended with postop MRI

Methods

Three image sets were analyzed for this study; intraoperative O-arm, postoperative MRI T1 (1.5T), and postoperative CT. O-arm images of the DBS electrodes were collected during implantation in the subthalamic nucleus using microelectrode mapping in patients with Parkinson's disease.

The margins of the STN were identified with microelectrode recording as a transition from white matter into typical multicellular fields with high background noise. If less than 4 mm thickness of STN was encountered an O-arm image was obtained of the microelectrode at target depth, and a second trajectory was chosen based on the location of the microelectrode on O-arm image blending. The impact of microelectrode mapping on final DBS electrode positioning was evaluated.

O-arm images were fused to postoperative MRI and CT scans. The stereotactic coordinates for the tip of the electrode were measured individually on each type of image. Paired differences in the x,y,z coordinates and the Euclidean radial distances between the modalities were compared.

Results

In 71 consecutive DBS electrodes the average radial difference of the tip of the DBS electrode between the O-arm and MRI was 1.55 ± 0.58 mm, between the O-arm and CT it was 1.03 ± 0.61mm. This data indicates that the O-arm image accurately predicted the location of the electrode compared to postoperative MRI and postoperative CT .

The most ***common*** surgical utility of the O-arm was to anatomically confirm the location of the DBS electrode during the surgery. However, the most ***valuable*** utility of the O-arm occurred when the microelectrode recording did not confirm the optimum region of the STN, and additional microelectrode passes were needed to neurophysiologically identify the STN, which occured in 1 out of 4 electrodes.

A single microelectrode pass confirmed the STN in 70% of electrodes. The implantation depth of the 3389 DBS electrode was adjusted such that contact 0 was at the ventral edge of the STN based on microelectrode findings. The tip was adjusted an average 1.6 ± 1.1 mm deeper than the initial target.

Average Paired Differences of Electrode Tip

	MRI – CT	MRI – O-arm	CT – O-arm	O-arm – O-arm
Lateral (mm)	0.12 ± 0.56 (1.7)	0.11 ± 0.54 (1.5)	0.02 ± 0.44 (1.3)	0.05 ± 0.33 (0.6)
AP (mm)	0.63 ± 0.72 (2.0)	-1.07 ± 0.79 (2.6)	0.45 ± 0.57 (2.0)	0.01 ± 0.45 (1.2)
Vertical (mm)	0.82 ± 0.81 (2.8)	0.34 ± 0.78 (2.3)	0.46 ± 0.76 (3.1)	0.20 ± 0.43 (1.2)
Vector (mm)	1.43 ± 0.66 (3.0)	1.55 ± 0.58 (2.9)	1.03 ± 0.61 (3.7)	0.62 ± 0.33 (1.4)
	n = 71	n = 71	n = 71	n = 15

The average ± SD (maximum) paired differences of the tip of the DBS electrode between the different modalities. The average vector distance between the electrode tips between the 3 imaging modalities estimates the error between these images.

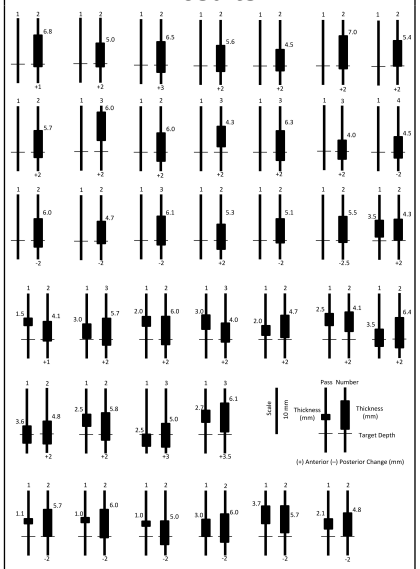
Average Stereotactic Coordinates of Electrode Tip

	MRI	CT	O-arm
Lateral	11.5 ± 1.1	11.6 ± 1.1	11.6 ± 1.0
AP	-4.8 ± 1.2	-4.1 ± 1.1	-3.7 ± 1.2
Vertical	-4.5 ± 1.4	-5.3 ± 1.6	-4.9 ± 1.5

Average ± SD stereotactic coordinates for the DBS Electrode tip (3389) in the STN (n = 71 leads)

In 15% of cases, if the DBS electrode had been inserted to target without microelectrode recording, and shown on O-arm to be at target, it would have been ouside the acceptable region of the STN. In these cases the microelectrode did not find sufficient or any STN at the target (see Figure).

Microelectrode Mapping Results



Microelectrode passes where the STN was missed are displayed. This shows the degree of spatial resolution of microelectrode mapping

Conclusions

Intraoperative O-arm images accurately depict the location of the DBS electrode compared to postoperative CT and MRI, with similar accuracy to intraoperative CT and MRI.

However, microelectrode recording provides superior sub-nuclear spatial resolution. Thus, microelectrode mapping and intraoperative imaging are both effective tools that can be combined for more accurate DBS electrode placement.