Interdisciplinary Neurosurgery: Advanced Techniques and Case Management 2 (2015) 29–39

Contents lists available at ScienceDirect

Interdisciplinary Neurosurgery: Advanced Techniques and Case Management

journal homepage: www.inat-journal.com

Technical Notes & Surgical Techniques

Some technical nuances for deep brain stimulator implantation

Cole A. Giller, MD, PhD, MBA *, Patrick Jenkins, PA

Department of Neurosurgery, Georgia Regents University, Augusta, GA USA

ARTICLE INFO

Article history:
Received 22 September 2014
Accepted 2 November 2014

Keywords:
Deep brain stimulation
Dystonia
Essential tremor
Microelectrode recording
Parkinson's disease
Stereotactic surgery

ABSTRACT

Protocols for deep brain stimulator (DBS) implantation vary significantly among movement disorders centers despite the need to address similar operative problems. The general steps of this procedure are well accepted, but there are many seemingly minor, yet important nuances not extensively discussed in published descriptions. A classification and the details of the nuances adopted by a single institution may therefore be helpful in providing a basis for discussion and comparison. We describe operative nuances adopted at the Georgia Regents Medical Center (GRMC) for DBS implantation that may not be universally employed. The problems of DBS implantation considered here include stereotactic planning, draping, creation and use of the burhole, physiological testing, anchoring of the electrode, financial considerations, and overall technique. Fourteen categories of operative nuances were identified and described in detail. These include the use of specific anatomical relationships for planning, the use of clear and watertight drapes, countersinking of the burhole, the use of gelfoam and tissue glue to seal the burhole, methods to review the entire microelectrode data simultaneously, blinded communication with the patient during macrostimulation, fluoroscopic marking, MRI compatible protection of the electrode tip, financial considerations effecting choice of operative materials, and restriction to a single operator. The majority of these have not been extensively described but may be in use at other centers. The many operative problems arising during DBS implantation can be addressed with specific technical nuances.

Introduction

Although there is consensus for the general requirements for DBS implantation such as the need for imaging, there are little Class I data to support any particular approach [1]. Accordingly, the operative details for this procedure vary between centers depending on the specific local surgical philosophies and opinions. Several centers have published excellent reviews of the operative techniques they have chosen [2–4], many of which have been adopted by others. In addition to these techniques, however, procedures as complex as DBS implantation also contain many steps that seem minor but that are essential for success. Such nuances often escape the general published descriptions, are often not universally adopted, and are not described by any systematic method for their classification. Believing that a description of the local practices of a single institution can be helpful in guiding discussion and comparison of the various surgical options, our goal in this work is to classify and describe some minor nuances of DBS implantation that have been helpful at our institution.

We describe these nuances without giving Class I data to justify their use for two reasons. First, many would be difficult to study in this fashion. For example, the method of draping with clear plastic sheets is widely used and is thought to improve communication between surgeon and anesthesiologist and patient, minimize patient claustrophobia, and (as we comment later) may have financial implications for the DBS program. However, choosing meaningful endpoints for a randomized, controlled trial of draping has inherent problems that may be prohibitive. The second reason we do not offer Class I evidence for each of the chosen nuances is that our goal is to describe a complete collection of minor methods that we have found helpful for DBS implantation. Including Class I data to justify each of these many techniques is well beyond the scope of a single article.

We do not claim that our protocols are the only way to address the operative problems of DBS implantation, nor do we claim that our methods are superior to others. Instead, we wish to convey our sense of the craft of this procedure rather than its science. Our hope is that an aggregate description of these small but important nuances may be helpful by drawing attention to the many problems inherent to DBS, suggesting a method for their classification, and suggesting a few possible approaches to their solution.

Operative techniques

Our nuances are grouped into the following categories: stereotactic planning, draping, burhole issues, physiological testing, electrode anchoring, financial considerations, and overall technique.

* Corresponding author at: Department of Neurosurgery, Georgia Regents University, 1120 15th Street, Augusta, GA 30912. Tel.: +1 706 721 3071; fax: +1 706 721 8084.
E-mail address: cgiller@gru.edu (C.A. Giller).

http://dx.doi.org/10.1016/j.inat.2014.11.001

Stereotactic planning

Nuance 1: stereotactic planning

No single method for localization is perfectly accurate [1,5–7], and so we apply each method in a 'round-robin' fashion, modifying the target and trajectory at each step and repeating iteratively until the resulting trajectory best satisfies all of the requirements.

Subthalamic target. As is commonly done, we first align an inversion recovery MRI sequence obtained with a stereotactic frame in place to the AC–PC plane. This sequence is then used as the reference to merge with all other available sequences (including a preoperative 3 T MRI in the axial and sagittal planes, a CUBE FLAIR sequence reconstructed in all three planes, and the 1.5 T MRI inversion recovery sequences in the sagittal plane obtained on the day of surgery) so that the coordinates it carries are not altered. All sequences are merged to avoid errors later in the procedure. We then cycle through our criteria for subthalamic nucleus (STN) targeting listed in Table 1.

The modified axial slice most likely to contain our target is identified, usually as the first slice superior to the optic tract containing parts of the AC, mamillothalamic tract (MMT), and the red nucleus (see Table 1). As others have done [2,5,6,8,9], we use the anterior border of the red nucleus and the MMT as landmarks for the mid-segment and anterior border of the STN, respectively (Fig. 1). Forel's field H2 lies as a hyperdensity adjacent to the MMT, and should not be confused with the anterior pole of the STN. We then choose a target based on these criteria. A distance of the target to the midline of less than 11 mm or greater than 13 mm is cause to proceed with great caution.

The sagittal anatomy is then reviewed using direct sagittal acquisitions and sagittal reconstructions. The STN is often directly visualized as a hyperdense structure in these images, as is the thin, hypodense zona incerta marking the roof of the STN [10]. Furthermore, because the STN lies within the angle formed by the descending internal capsule and the hypodense substantia nigra (SN), visualization of these two structures yields another clue for STN localization. In addition, the SN serves to locate the STN floor and guides our superior–inferior coordinate. Choosing the sagittal slice showing the greatest amount of STN, we place the target approximately 2 mm anterior to the midpoint of the STN at the superior boundary of the SN. A more posterior site may be too close to the adjacent internal capsule because the posterior STN is very narrow.

We then review the 'probe view' that displays the entire trajectory as a colored line in one oblique plane, and the intersection of the trajectory as a colored dot superimposed upon the perpendicular plane. The appearance of this dot within the SN confirms that the trajectory passes through the STN floor, and the appearance of the dot within the STN using the inversion recovery sequences (which is often well seen as a linear hypodense structure in these oblique images) confirms targeting.

Table 1
Criteria for localization of subthalamic nucleus (STN).

3 T MRI sequences fused to operative 1.5 T sequences
Orient dataset to AC–PC plane
Use vertical axis of 3rd ventricle rather than interhemispheric plane for orientation
Start with slice containing parts of anterior commissure, mamillothalamic tract and red nucleus (corresponding to Hv-3.5 or Hv-4.5 on Plates 54 or 55 of SWA[a])
Anterior border of red nucleus marks midpoint of STN
Mammillothalamic tract marks anterior border of STN
Distance to midline should be approximately 12 mm
Forel's H2 should not be mistaken for anterior STN
STN lies within angle formed by internal capsule and substantia nigra on sagittal slice, and inferior to zona incerta
Target should be at midline of STN on sagittal slice (not posterior)
Target should be just superior to substantia nigra on sagittal slice and probe view
Target should be within hypodense STN seen on probe view
Use of resident Schaltenbrand–Wharen atlas
Symmetry to contralateral side if prior electrode has been placed

[a] SWA = Schaltenbrand–Wharen atlas [8].

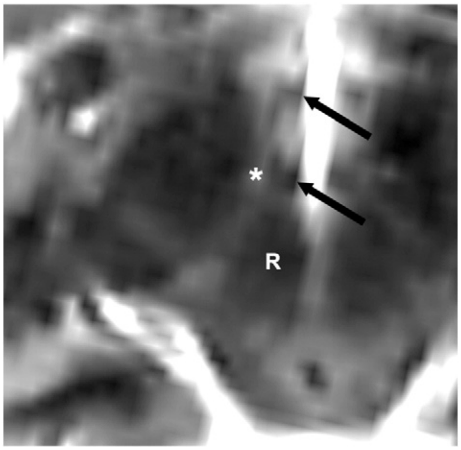

Fig. 1. Axial inversion recovery MRI image showing fornix (upper arrow), mamillothalamic tract (lower arrow), the area of H2 and the ansa lenticularis (*) and the red nucleus (R).

We also use images of the stereotactic atlas that are loaded within our planning software, deforming them in perpendicular directions to best match the MRI images. Because the putamen and globus pallidus are usually easy to identify, deformations are made to match these structures to the atlas. The deformation software is limited, however, and it can be difficult to obtain a close match between the atlas and the MRI image. We have found it helpful to import the contours of the atlas together with the MRI image into image software (Photoshop, Adobe, San Jose, CA). The 'warp' option allows portions of the image to be deformed separately, so that a precise match of landmark structures such as the fornices, the MMT, red nucleus, putamen and globus pallidus is possible (Fig. 3).

The FLAIR sequences reconstructed from the CUBE acquisition usually clearly demonstrate the combined signal of the STN and SN, thus providing further confirmation of the target position.

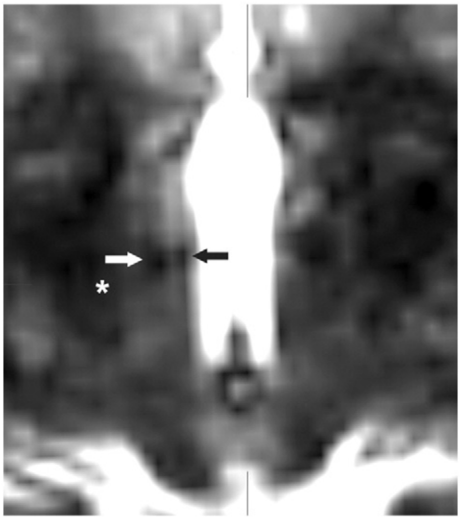

Fig. 2. Axial inversion recovery MRI image showing mamillothalamic tract (black arrow), H2 (white arrow) and region of VIM (*). The contralateral mamillothalamic tract and H2 can be seen but not distinguished from each other.