

Surgery for Movement Disorders

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VENTROLATERAL THALAMOTOMY	1
PREOPERATIVE.....	1
INTRAOPERATIVE.....	1
POSTOPERATIVE.....	2
THALAMIC DEEP-BRAIN STIMULATION (DBS)	2
PALLIDOTOMY	2
PREOPERATIVE.....	2
INTRAOPERATIVE.....	2
POSTOPERATIVE.....	3
PALLIDAL / SUBTHALAMIC NUCLEUS DEEP-BRAIN STIMULATION (DBS)	3

Ventrolateral Thalamotomy

INDICATIONS

- 1) **tremor** (parkinsonian, intention, essential) refractory to medication
distal upper-extremity tremor responds best!
- 2) rigidity
- 3) dystonia, chorea, hemiballism, athetosis, some types of myoclonus.

CONTRAINDICATIONS

- 1) parkinsonism-plus syndromes
- 2) predominance of bradykinesia and rigidity
- 3) \geq moderate cognitive dysfunction

PREOPERATIVE

- *medications are not given on surgery morning* - to accentuate symptoms for intraoperative testing.
- minimal shave.
- place **stereotactic frame** parallel to orbito-meatal line (approximately parallel to anterior commissure-posterior commissure (AC-PC) line).

GUIDANCE

Historical – intraoperative **ventriculography** – relates target position to anterior and posterior commissures.

Modern (i.e. image-guided, computer-assisted thalamotomy):

- a) **CT**
 - b) **MRI**
 - c) **CT/MRI coregistration** (MRI provides high anatomical resolution, while CT eliminates potential inaccuracy from MRI distortion).
+ intraoperative **electrophysiological** testing.
- CT 1-3 mm cuts parallel to frame, from skull base to vertex (plus contrast for coregistration with prior volumetric [SPGR] contrast-enhanced MRI); high-resolution MRI sequences with functional CRW frame and fiducial localizer.
 - anterior commissure (AC): 3-4 mm below foramen of Monro.
 - posterior commissure (PC): 1 mm above superior colliculi, 1 mm below pineal recess.

INTRAOPERATIVE

- patient *supine* (just as during scan - to prevent any shifting of target) or *sitting up* with strap to avoid downward slip.
- anesthesia on left, nurse on right.
- *patient must be awake* (use short-acting or reversible anesthetic [propofol, midazolam, fentanyl] during burr-hole procedure).
- make sure that hands and feet are free and visible for testing; drapes placed to keep face exposed.
- enlist neurologist for intraoperative testing (optional but very helpful).

TARGET - **ventrolateral (VL) nucleus**:

- for TREMOR - **posterior VL (bottom of ventral intermediate [VIM] nucleus in VL thalamus)** - $\frac{1}{4}$ of distance of AC-PC line, in front of PC, either 11 mm lateral from wall of 3rd ventricle or 13-15 mm lateral to AC-PC line.
- for RIGIDITY - **anterior VL**.

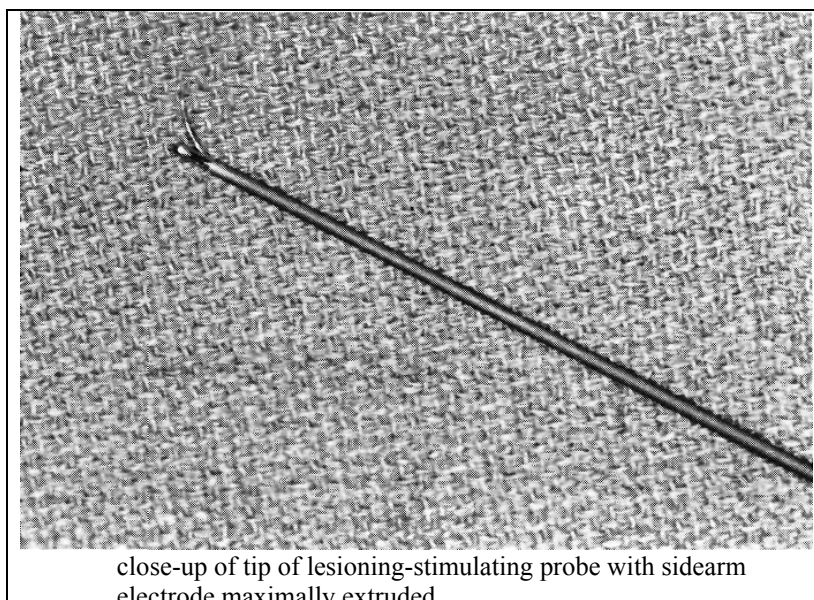
ENTRY POINT

- 3-4 cm off midline, in vicinity of coronal suture.
- use large enough perforator to allow multiple trajectories and to visualize pia.
- 7/64-inch **twist drill hole** is used (with **burr-hole**, air often enters subarachnoid space → potential target shifting).

Trajectory must avoid passing through cortical vein, sulci, and ventricle!

STIMULATING-LESIONING ELECTRODE is passed to **posterior VL nucleus**.

- stop 1 cm above target.
- *impedance* is confirmed to be neither 0 nor off scale (indicating cable or electrode breaks).
- *thermistors* should indicate body temperature.
- examine patient.
- advance electrode to target.
- examine patient - symptoms may improve with correct placement of electrode.



1. **MACROSTIMULATION MAPPING** with low-amplitude stimulation (constant 0.1 mA current or changing voltage) - side-extruding component of electrode is slowly advanced in 1-mm increments:
 - 1) **sensory testing**: side-extruding component (stimulating at 50-60 Hz, 1 msec duration, 1-3 V) is advanced **posteriorly** - toward somatosensory **nucleus ventralis posterior (VP)** - contralateral PARESTHESIAS at < 1 V identify **VL-VP junction**.
- this **junction** should be 3 mm* posterior to main shaft of electrode.

- distal hand (esp. thumb) and face responses indicate optimal laterality (*target is just anterior to thumb area!*)
 - leg responses indicate too lateral position → move medial.
 - facial paresthesia only or respiratory inhibition suggests placement is too medial.
- 2) **motor testing**: side-extruding electrode (stimulating at 2-5 Hz, 1 msec duration, 1-2 V) is advanced *laterally* – toward *internal capsule* - CLONIC CONTRACTIONS of contralateral limbs at < 1 V identify **thalamo-capsular border** (junction of lateral border of thalamus and posterior limb of internal capsule)
- this **border** should be at least 3 mm* lateral to main shaft of electrode.
- *for 6-mm lesion.

With proper placing:

tremor arrest should occur at 50 Hz, 1 msec duration, 1-3 V

tremor driving should occur at 2 Hz, 1 msec duration, 1-2 V

2. **LESIONING** (examine patient during and after lesion):

- 1) **"test" (reversible) lesion** - by heating probe to 42-44°C for 60 sec
- 2) if no unwanted side effects (contralateral paresis or sensory deficit) occur → **complete lesion** by heating probe to 60-80°C for 60 sec – lesion must be 4-6 mm in diameter (lesion size is proportionate to temperature and dimensions of uninsulated electrode tip);
 - raise electrode 3 mm and make second lesion;
 - raise electrode 3 mm and make third lesion.

This is effective in 90% **TREMOR** cases (parkinsonian, essential, intention tremors).

- **larger lesions** are necessary to control *high-amplitude tremors* (e.g. cerebellar intention tremor) or any involuntary movements affecting *proximal muscles*.
- **small lesions** are indicated for *low-amplitude* primarily *distal* tremors (e.g. younger hemiparkinsonian patients).
- more medial lesions are used for UPPER EXTREMITY, and more lateral lesions - for LOWER EXTREMITY.

For **RIGIDITY**, second lesion in **anterior VL nucleus** is required.

- electrode is withdrawn from initial position and repositioned at **junction of anterior and middle thirds of VL nucleus** (several millimeters medial to target for tremors).
- low-frequency stimulation verifies proper electrode position - ELEMENTS OF MOVEMENT DISORDER must be reproduced.
- often, it is necessary to destroy majority of VL nucleus to correct such movement disorders.

BILATERAL VL LESIONS

N.B. bilateral VL lesions can cause permanent *cognitive & verbal deficits* (even unilateral large thalamotomies on language-dominant side may cause verbal deficits).

- perform *initial lesion* on non-language-dominant side.
- *second-stage contralateral lesion* is less likely to result in permanent neurological sequelae if it is:
 - smaller
 - in different area (e.g. globus pallidus)
 - performed ≥ 6 months later.

POSTOPERATIVE

- admit overnight for observation.
- no routine early postoperative imaging.
- home after 24 hours if no problem.

Thalamic Deep-Brain Stimulation (DBS)

- macroelectrode insertion *steps are similar to stereotactic thalamotomy*.
- stimulation can be carried out through **DBS electrode**.
- electrode is *clipped* at dural surface (with Weck clip) - to avoid movement and mark position; it is then anchored at burr hole with bioplate.
 - some surgeons use intraoperative fluoroscopy to ensure that electrode position does not change.
- *scalp is closed* after coiling electrode beneath scalp flap.
- general anesthesia for *pulse generator implantation* and *electrode tunneling* with ventriculoperitoneal shunt tunneler.

Pallidotomy

INDICATIONS

- 1) disabling parkinsonian **"offs"**
- 2) antiparkinsonian drug-induced **dyskinesias**
- 3) parkinsonian **tremor** (better helped by STN than globus pallidus (GPi) targeting!)

CONTRAINDICATIONS

- 1) parkinsonism-plus syndromes
- 2) lesion on contralateral side (if DBS is not available)
- 3) ≥ moderate dementia
- 4) unresponsiveness to levodopa

PREOPERATIVE

Image-guided stereotaxy – analogous to **thalamotomy**. *see above >>*

N.B. **micro- & macro-electrode** guidance is useful!

- *medications are not given on surgery morning* - to accentuate off symptoms for intraoperative testing and minimize intraoperative movement.
- enlist **neurologist** - for intraoperative testing (optional but very helpful).
- enlist **neurophysiologist** - for intraoperative microelectrode recording.

INTRAOPERATIVE

patient positioning, anesthesia, draping, entry point – as in **thalamotomy**. *see above >>*

TARGET - posteroventral globus pallidum interna (GPi)

- 2 mm anterior to midcommissural point, 3-5 mm inferior and 20-23 mm lateral;
- fine-tune target to MRI landmarks: just above optic tract; lateral to internal capsule; at level of mammillary bodies (on coronal slice).

TARGET - **subthalamic nucleus** - 4 mm posterior, 4 mm inferior, and 12 mm lateral to midcommissural point.

1. **ELECTRODE IS PASSED TO TARGET** *see above >>*

- place rigid guide sleeve to 30 mm above target depth; microelectrode is then advanced to target.

2. **MICROELECTRODE RECORDING** (requires experienced electrophysiologist):

pallidum: 1-2 Hz to 10-15 Hz.

GPe: infrequent bursts and gaps in recording.

laminar neurons: regular firing rate 2-3 Hz to 15-20 Hz.

GPi: constant firing like "railroad train".

optic tract: silent; can stimulate with visual stimulus (flashing light).

STN: large asymmetrical spikes at 30-40 Hz and biphasic spikes at 10-13 Hz responsive to passive movement and tremor.

- electrophysiological map is compared with Schaltenbrand Atlas → electrode moved to optimal position.

MRI gets you near target, but physiology proves that you have exact spot!

3. **MACROELECTRODE STIMULATION**

- macroelectrode (or DBS electrode) inserted.
- symptoms may improve when electrode enters target.

1) **motor testing**: 5-6 Hz, 1 msec, 2-3 V; for GPi - contralateral synchronous motor twitches at < 2 V indicate proximity to internal capsule → move more lateral or anterior.

2) **induction of tremor / dyskinesia** (sign of good localization): 50 Hz, 1 msec, 1-2 V
higher voltages can induce hypertonicity and speech arrest (dominant side)

3) **visual scotomata** indicate proximity to optic nerve → raise electrode.

4) **impedance measurements**:

- leaving white matter and entering pallidum - impedance as for gray matter;
- impedance drops when entering ambient cistern, indicating electrode too deep (GPi)

4. **LESION GENERATION** (examine patient during and after lesion)

temporary lesion: 60° to 60 sec;

permanent lesion: 80° to 60 seconds.

- each lesion has 4 mm diameter.
- electrode raised for successive lesions to create desired height of lesion (based on prior mapping, usually 6-8 mm)

POSTOPERATIVE

- resume *Parkinsonian medications* immediately postoperatively.
- admit overnight for observation.
- no routine early postoperative imaging.
- home after 24 hours if no problem.
- **MRI** after 2-3 months.

Pallidal / Subthalamic Nucleus Deep-Brain Stimulation (DBS)

- confirmation of proper target by macrostimulation using DBS electrode.
"micro-thalamotomy" effects (local effects due to electrode pass before lesion) may make it impossible to do stimulation "on" testing because patient is already improved!
- DBS electrode fixation, etc – as in **thalamic DBS**. *see above >>*

BIBLIOGRAPHY for ch. "Movement disorders, Ataxias" → follow this [LINK >>](#)