Surgical Procedure – targeting, surgical steps and current approaches

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University Health Network
UNIVERSITY OF TORONTO

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International Parkinson and Movement Disorder Society Pan American Section

Operative Procedure, Testing and Recording

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UHN Krembil Brain Institute

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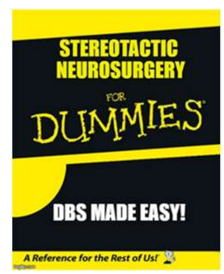
Objectives

- Understand goals and methods of stereotactic surgery
- Review of steps and workflow of DBS surgery including intra-operative testing
- Brief overview of intra-operative recording



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Goals of Surgery

1. Safe delivery of electrodes at optimal therapeutic location/target
2. Optimization of therapeutic benefit and mitigation of off target side-effects
3. Complete system implantation with extension wires and IPG implantation

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Different Targets for DBS

Thalamus (Vim)
- Essential tremor
- Parkinsonian tremor
- Symptomatic tremor (Dystonic, MS, post-trauma, etc...)
- Task specific dystonia (Vo)

Globus Pallidum interna (GPi)
- Parkinson's disease
- Dystonia

Subthalamic nucleus (STN)
- Parkinson's disease
- Dystonia

MRI-visible targets

Modified from A. Fosano

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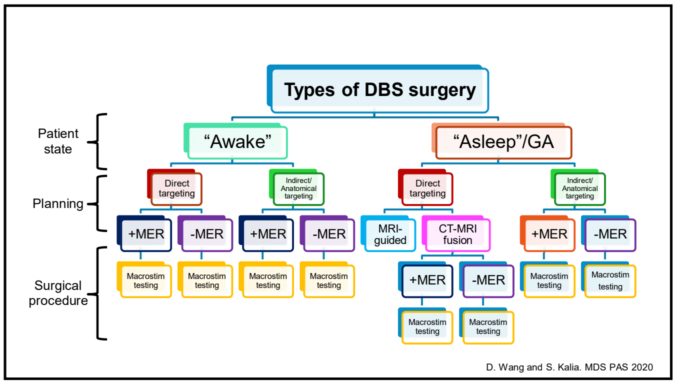
Types of DBS surgery
Patient state
Planning
Surgical procedure
"Awake"
"Asleep"/GA
Direct targeting
Indirect/ Anatomical targeting
+MER
-MER
MRI-guided
CT-MRI fusion
Macrostim testing
D. Wang and S. Kalia. MDS PAS 2020

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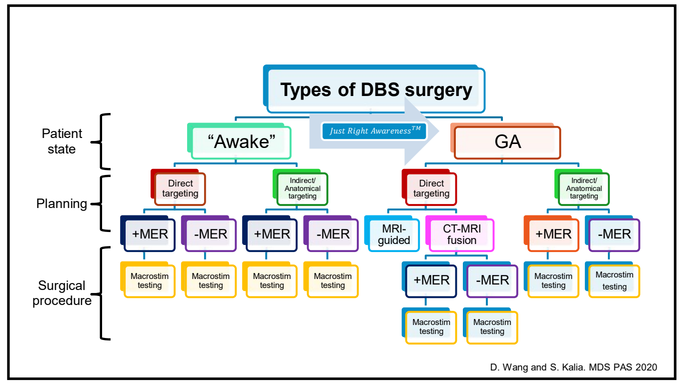
Types of DBS surgery
Patient state
Planning
Surgical procedure
"Awake"
Just Right Awareness™
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Direct targeting
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+MER
-MER
MRI-guided
CT-MRI fusion
Macrostim testing
D. Wang and S. Kalia. MDS PAS 2020

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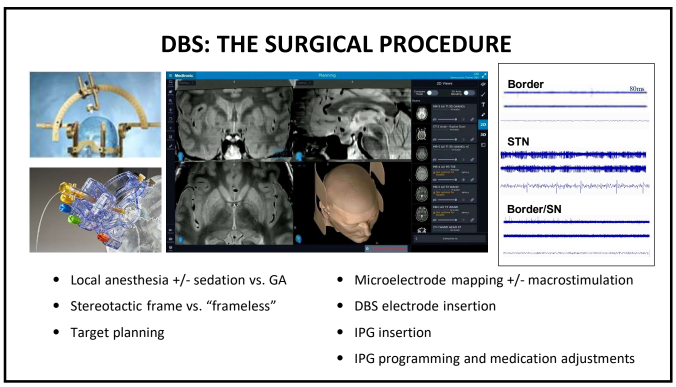
DBS: THE SURGICAL PROCEDURE
Border
STN
Border/SN
Local anesthesia +/- sedation vs. GA
Stereotactic frame vs. "frameless"
Target planning
Microelectrode mapping +/- macrostimulation
DBS electrode insertion
IPG insertion
IPG programming and medication adjustments

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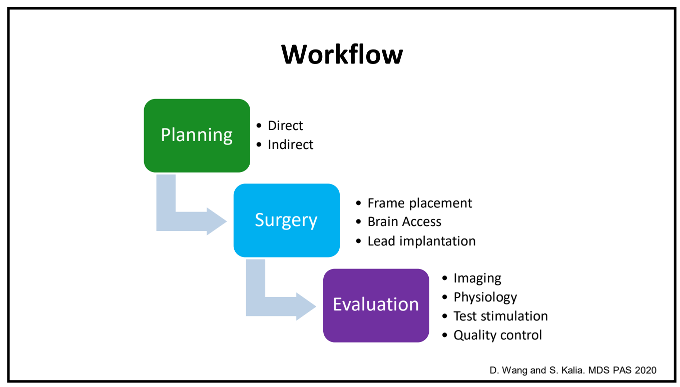
Workflow
Planning
Direct
Indirect
Surgery
Frame placement
Brain Access
Lead implantation
Evaluation
Imaging
Physiology
Test stimulation
Quality control
D. Wang and S. Kalia. MDS PAS 2020

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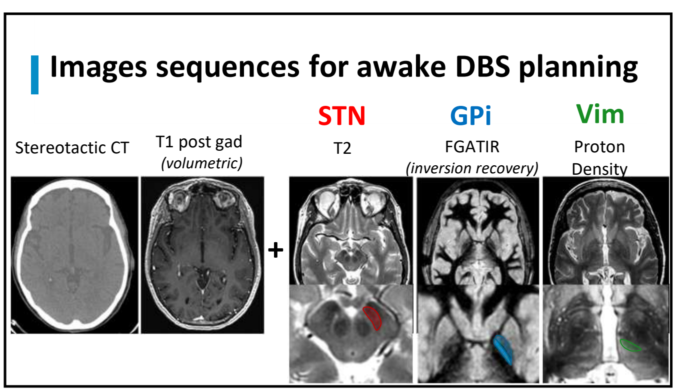
Images sequences for awake DBS planning
Stereotactic CT
T1 post gad
(volumetric)
+
STN
T2
GPi
FGATIR
(inversion recovery)
Vim
Proton
Density

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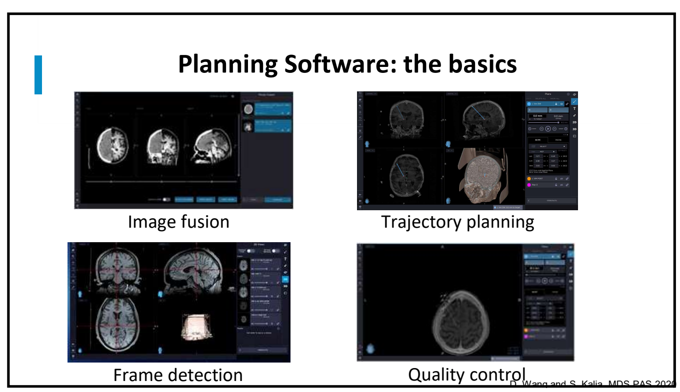
Planning Software: the basics
Image fusion
Trajectory planning
Frame detection
Quality control
D. Wang and S. Kalia. MDS PAS 2020

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Electrode Implantation: Frame vs. Frameless

Frame Based Navigation

- Planning software package that allows for stereotactic targeting with frames
  - Leksell (Elekta)
  - CRW (Integra)
- For functional neurosurgery, frame-based approaches remain accurate, economical and are the gold standard to which other approaches should be measured


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Electrode Implantation: Frame vs. Frameless

"Frameless" Navigation

- Planning software for disposable "mini-frame" platforms
  - NexFrame (Medtronic)
  - StarFix (FHC)
  - Clearpoint (MRI Interventions)
- Robotic solutions
  - Rosa
  - Renishaw





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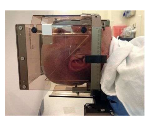
Stereotactic Frame Scan

- Varies from center to center
- Need to develop a highly accurate imaging protocol with the frame on and a fiducial localizer
  - 1.5T MRI with frame
  - CT with frame
  - Intraop CT with frame

**need to develop an appropriate and manageable flow for given patients at your institution*

**need to have tight quality control and understand potential inaccuracies that may be unique to your own site*

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Patient Positioning

Careful positioning to maximize patient comfort and minimize operative risks such as potential air embolism and aspiration is critical

TIPS

- Place head in sniff position to open upper airway
- Patient in "beach chair" position
- warm blanket around neck provides support and comfort


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Anesthetic Considerations

- Varies from center to center
- Propofol/Precedex + short acting anesthetic (fentanyl)
- Local anesthetic infiltration (short-acting + long acting)
- Nasal cannula +/- nasal trumpet or oral airway

TIPS

- Start sedation when patient arrives in OR (sedated during foley, frame placement, burr hole)
- Stop all sedation before making first tract (MER)
- Be aware of how drugs affect recordings




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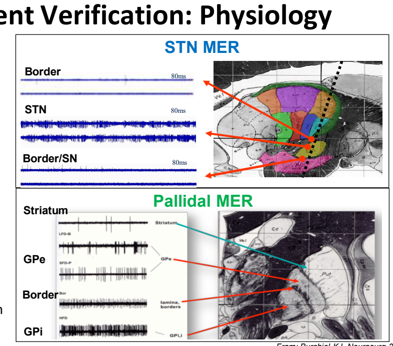
Lead Placement Verification: Physiology

Microelectrode Recording (MER)

- Many commercial amplifiers and recording systems available for intra-operative MER
- Work closely with neurophysiology team to optimize platform and quality of intra-operative recordings
- Goal is to define neurophysiological target
- Record –> microstim –> macrostim -> macromacrostim



From: Burchiel KJ, Neurosurg 2016

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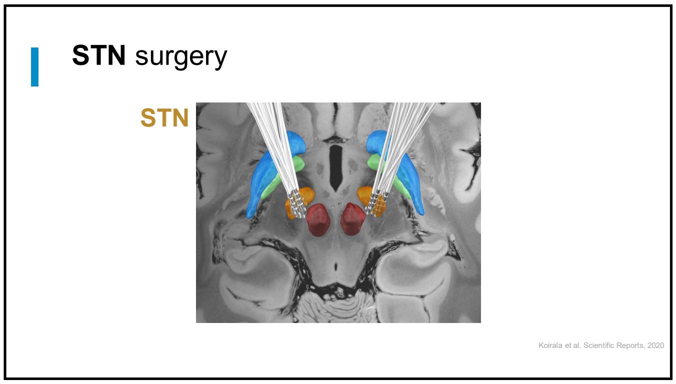

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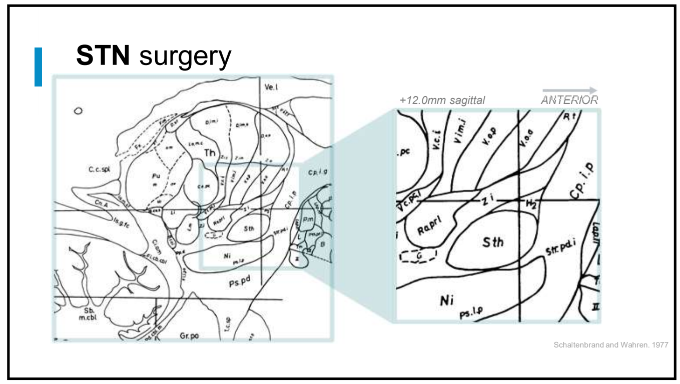

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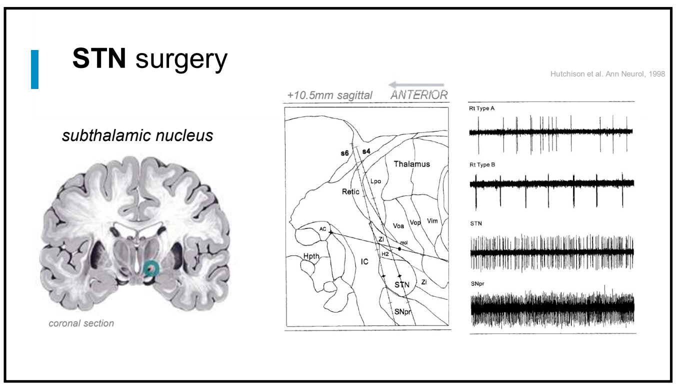

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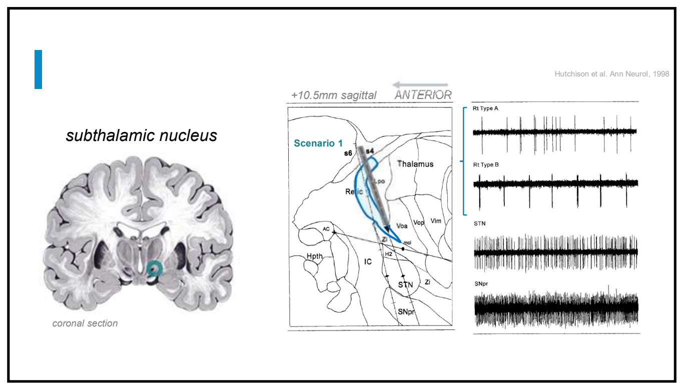

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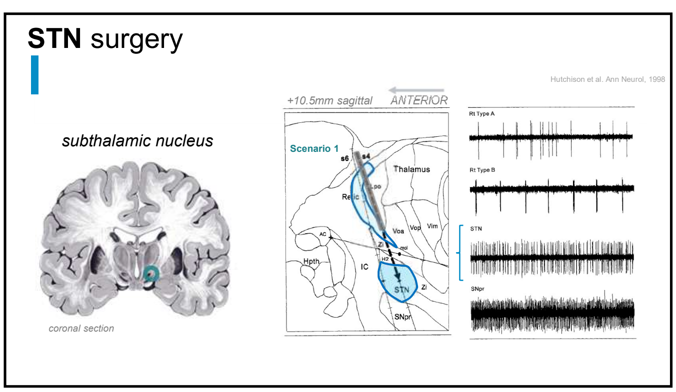

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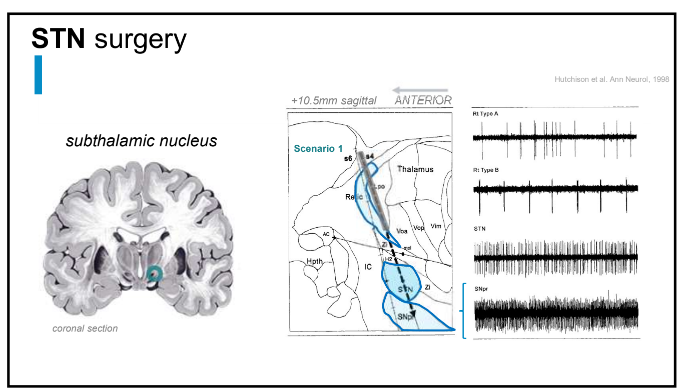

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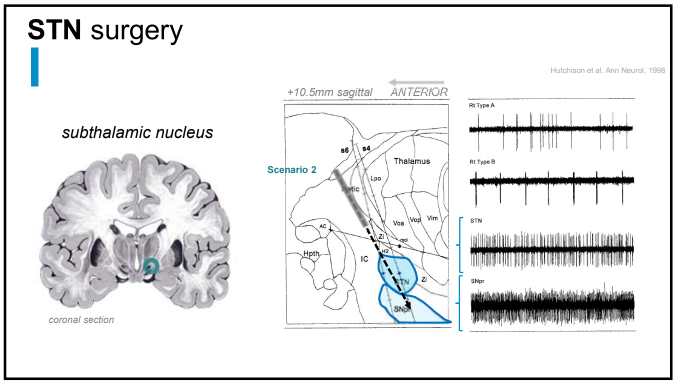

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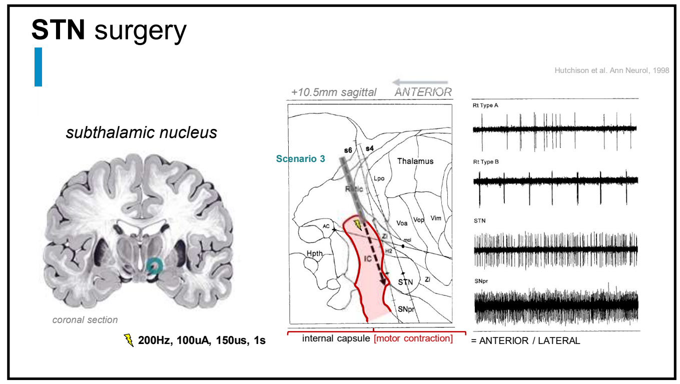

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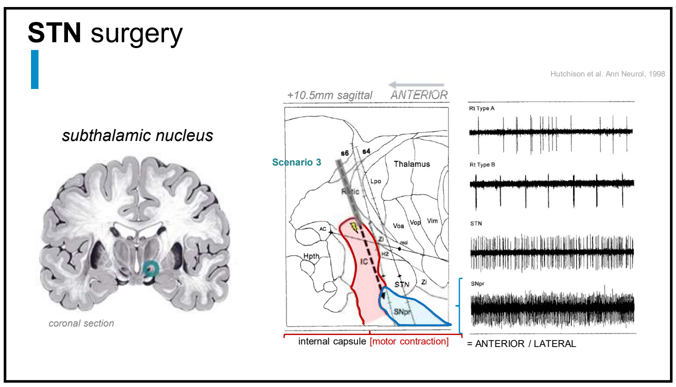

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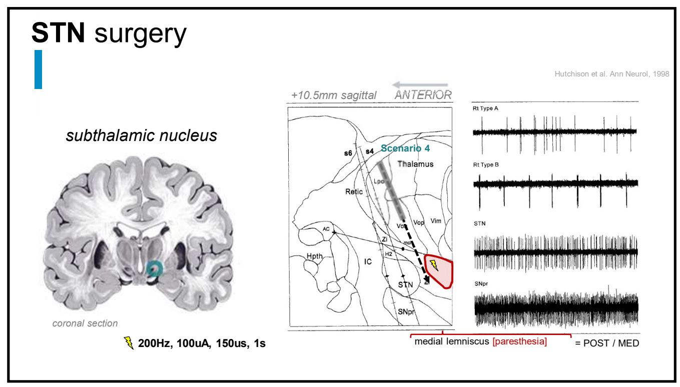

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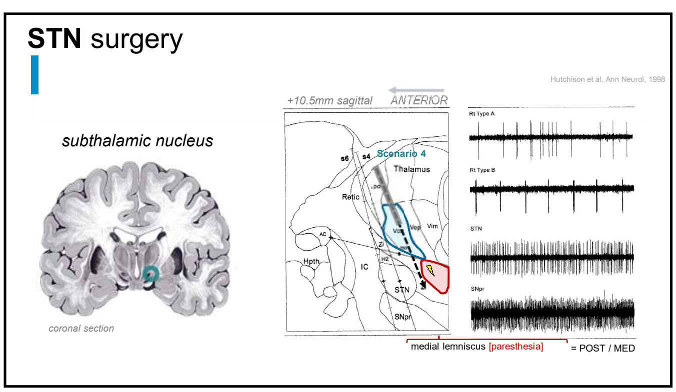

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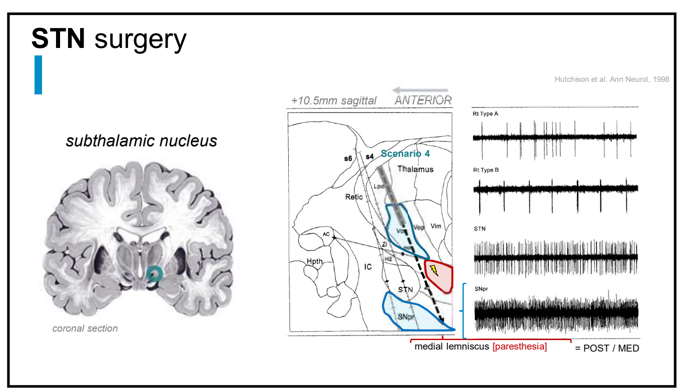

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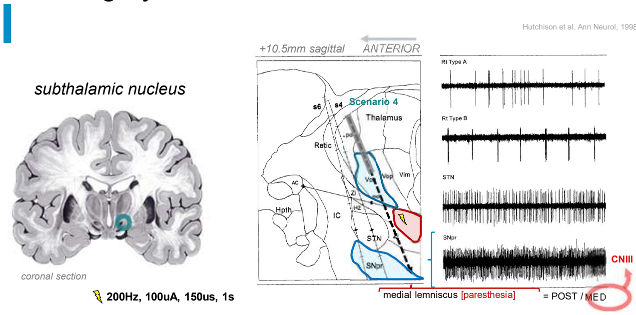
STN surgery



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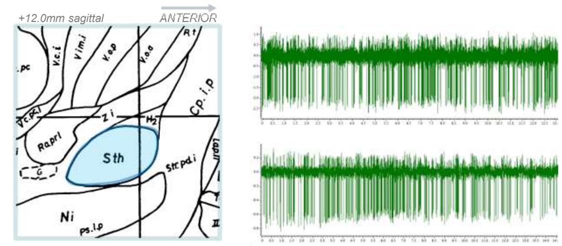
STN



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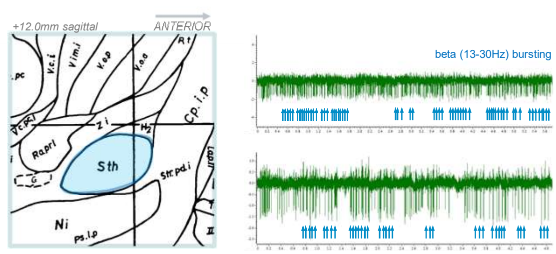
STN



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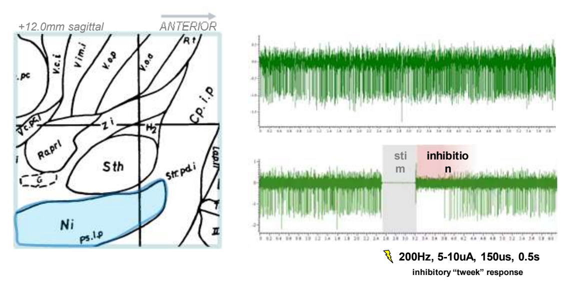
SNr



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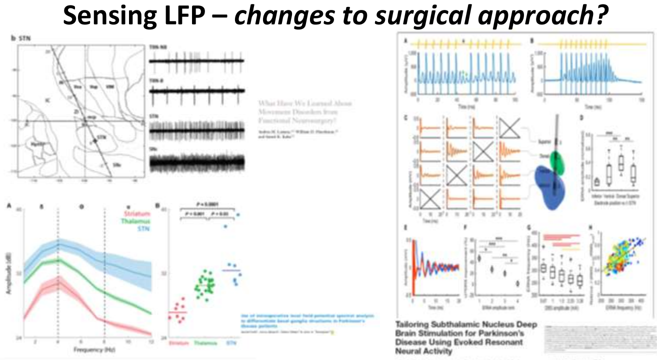
Sensing LFP – *changes to surgical approach?*



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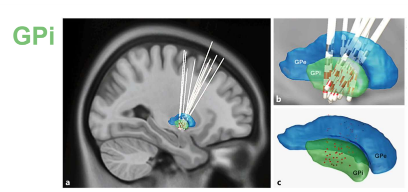
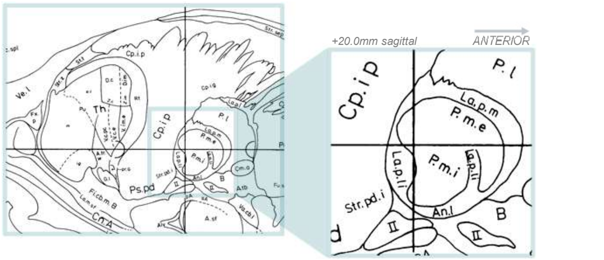
GPi surgery



Malekmohammadi et al. Stereotactic and Functional Neurosurg, 2018

36

GPi surgery



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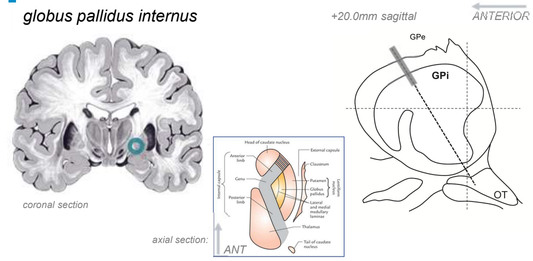
GPi surgery

globus pallidus internus



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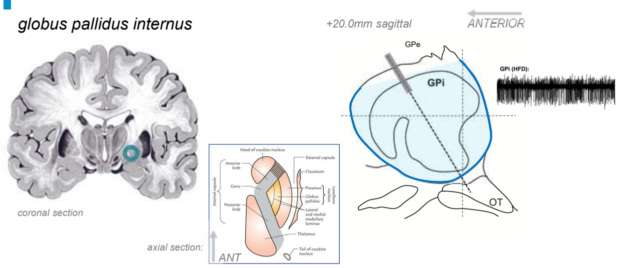
GPi surgery

globus pallidus internus



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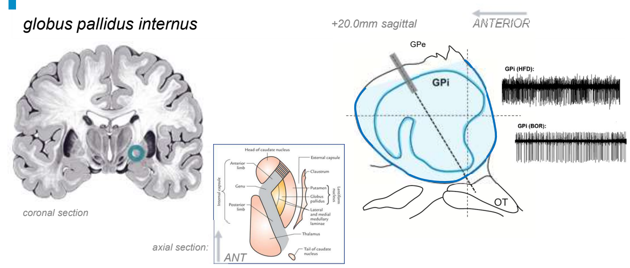
GPi surgery

globus pallidus internus



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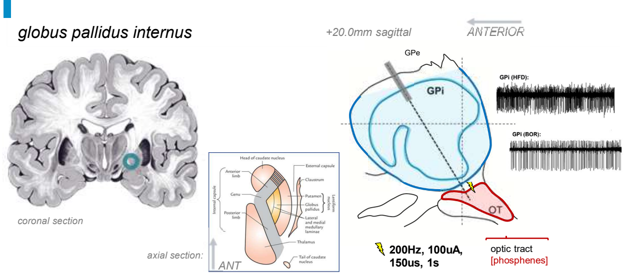
GPi surgery

globus pallidus internus



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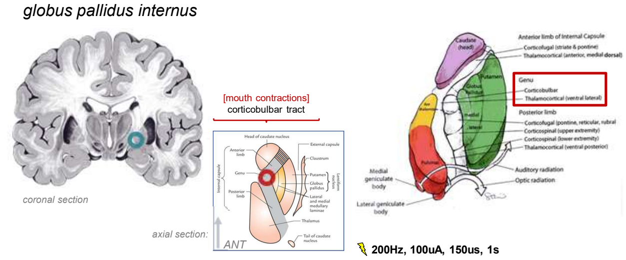
GPi surgery

globus pallidus internus



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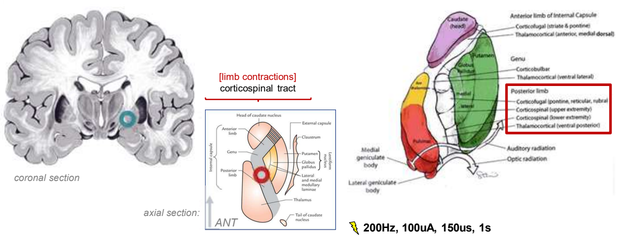
GPi surgery

globus pallidus internus



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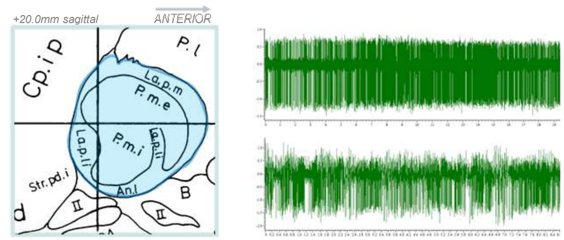
GPi surgery



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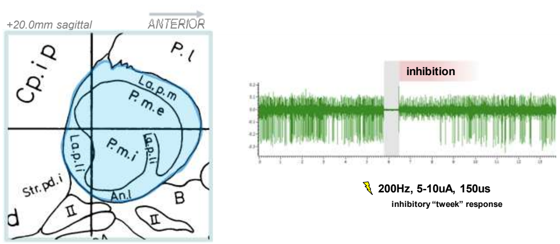
GPi surgery



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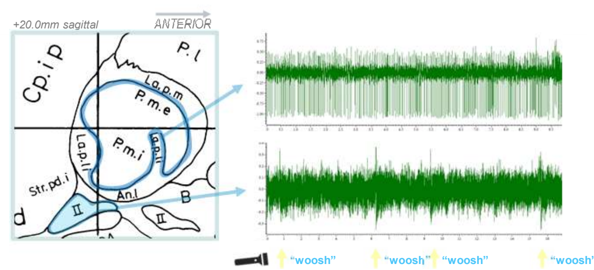
GPi surgery



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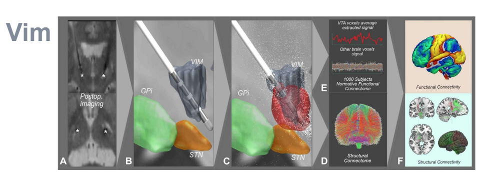
Vim surgery



Al-Fatly et al. Brain, 2019

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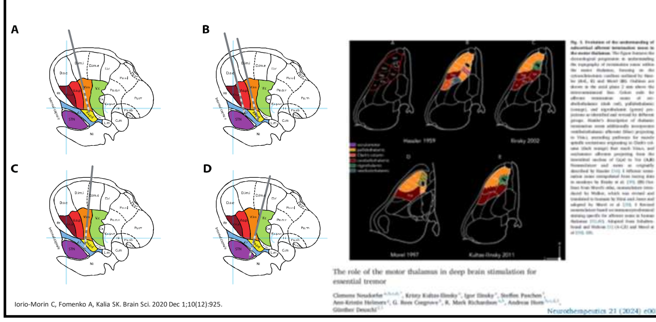
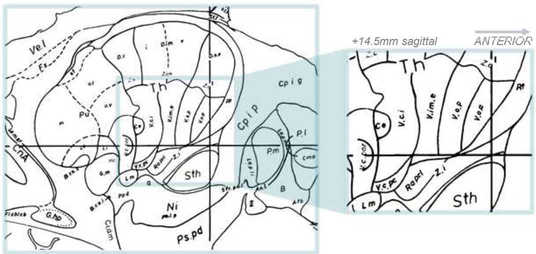
VIM and PSA for Essential Tremor



Iorio-Morin C, Fomenko A, Kalia SK. Brain Sci. 2020 Dec 1;10(12):925.

48

Vim surgery



Schaltenbrand and Wahren, 1977

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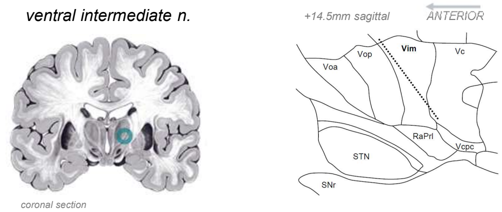
Vim surgery

ventral intermediate n.



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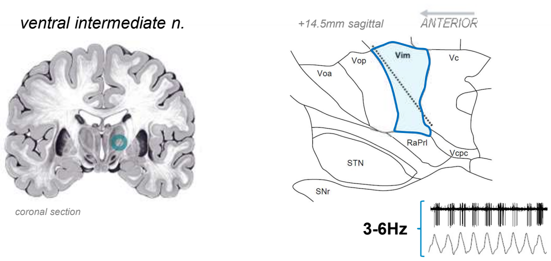
Vim surgery

ventral intermediate n.



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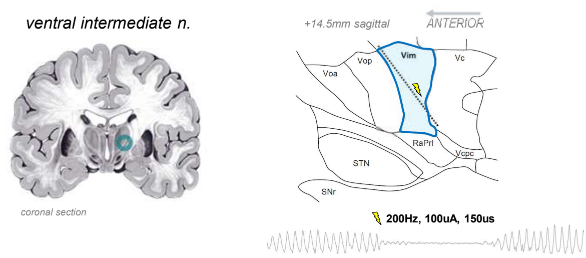
Vim surgery

ventral intermediate n.



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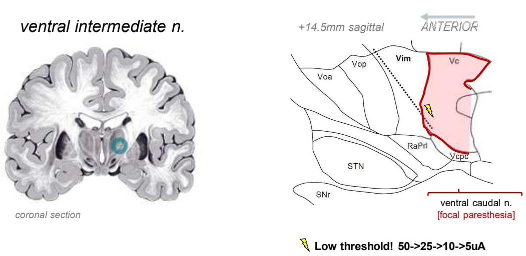
Vim surgery

ventral intermediate n.



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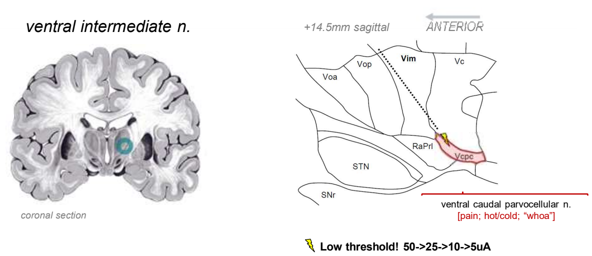
Vim surgery

ventral intermediate n.



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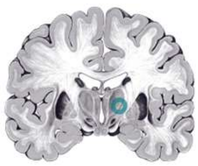
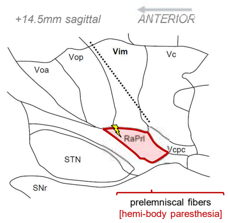
Vim surgery

ventral intermediate n.



coronal section



prelemniscal fibers
[hemi-body paresthesia]

High threshold! 50->100uA

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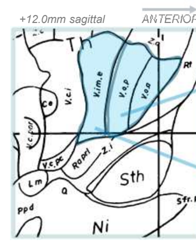
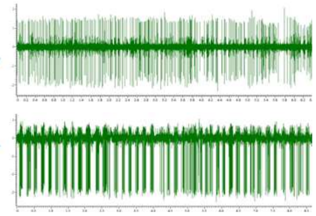
Vim surgery





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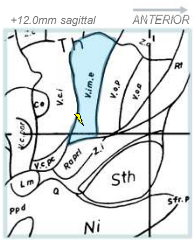
Vim surgery



200Hz, 100uA, 150us

tremor suppression

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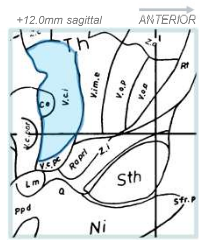
Vim surgery



superficial tactile response

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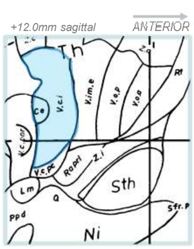
Vim surgery



deep tactile response

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Cheat sheet

STN surgery

Rt neurons:
slow (3-10Hz); irregular or bursty

STN neurons:
moderate (15-65Hz); irregular;
oscillatory; beta & tremor cells;
respond to limb movements

SNr neurons:
fast (70-120Hz); very regular;
“tweek” inhibition

PLIC (corticospinal)**:**
anterior/lateral to STN;
motor contraction / “pulling”

RaPrl (lemniscus fibers)**:**
posterior/medial to STN;
paresthesia / “tingling”

CNIII:
medial to SNr;
eye deviation / double-vision

GPi surgery

- **GPe neurons:**
  low-frequency (30-60Hz)
  bursts with pauses (LFB)
- **GPi “HFD” neurons:**
  fast (70-130Hz);
  irregular and bursty;
  respond to limb movements;
  “tweek” inhibition
- **Optic tract:**
  below GPi ~2mm;
  visually evoked potentials;
  phosphenes
- **PLIC** (corticospinal)**:**
  posterior to GPi;
  limb contraction / “pulling”
- **IC genu** (corticobulbar)**:**
  medial to GPi;
  mouth contraction / “pulling”

Vim surgery

- **Voa/Vop neurons:**
  moderate (15-60Hz); irregular;
  respond to limb movements
- **Vim neurons:**
  moderate (15-60Hz); irregular;
  tremor cells;
  respond to limb movements;
  tremor suppression / arrest
- **Vc** (lemniscus inputs)**:**
  superficial/deep tactile responses;
  low threshold focal paresthesia
- **VcPc** (spinothalamic inputs)**:**
  low threshold focal pain, hot/cold
- **RaPrl** (lemniscus fibers)**:**
  high-threshold hemi-body paresthesia

microstimulation settings

200Hz, 150us, **1s**, **100µA**
200Hz, 150us, **0.5s**, **5µA**

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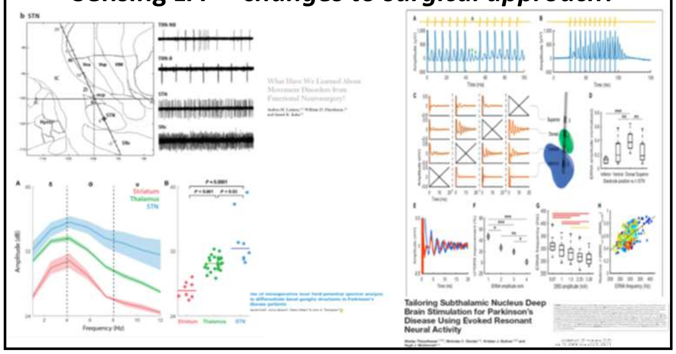
Sensing LFP – *changes to surgical approach?*



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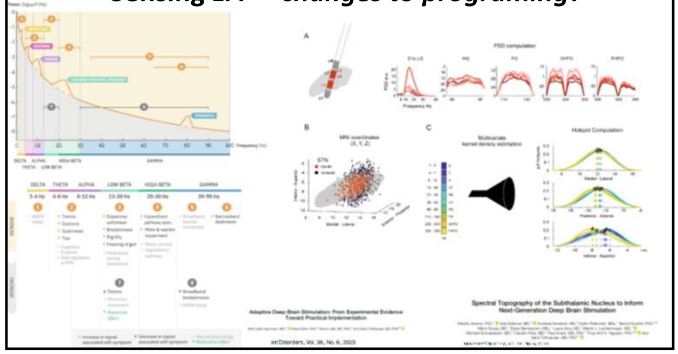
Sensing LFP – *changes to programing?*



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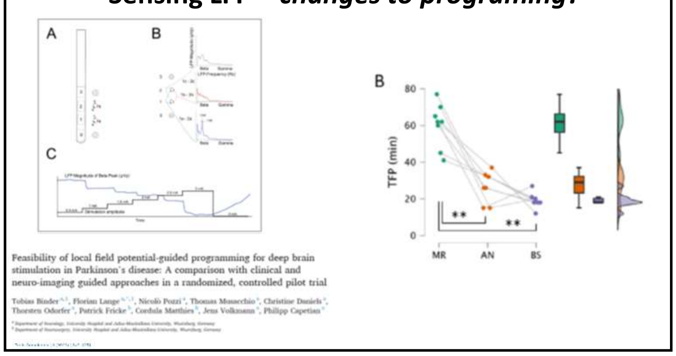
Sensing LFP – *changes to programing?*



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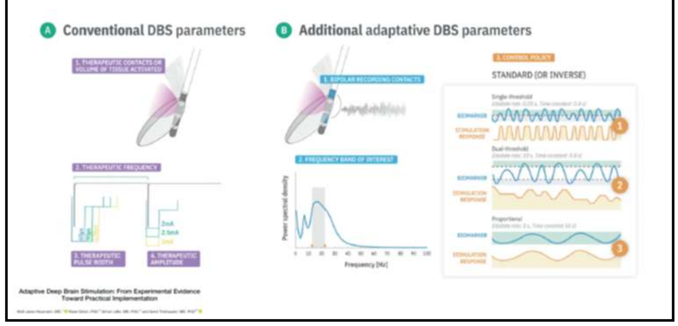
Sensing – *moving to closing the loop (aDBS)*



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Lead Placement Verification: Test Stimulation

- Microstimulation
  - through the microelectrode probe
- Macrostimulation
  - through DBS electrode
  - using patient screener and electrode implanted in physiological target

The goal is to maximize thresholds for side effects.

TIPS – be aware of micro-lesion effects when clinical testing

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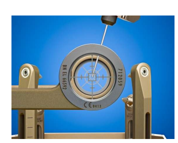
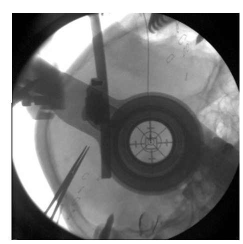
Lead Placement: Verification Imaging

Depending on your institution's current work flow and equipment availability

- **Fluoroscopy**
- Intraoperative CT
- Intraoperative MRI





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Lead Placement: Verification Imaging

Depending on your institution's current work flow and equipment availability

- Fluoroscopy
- **Intraoperative CT**
- Intraoperative MRI

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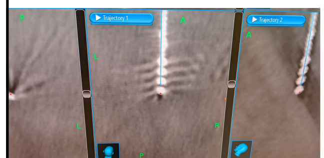
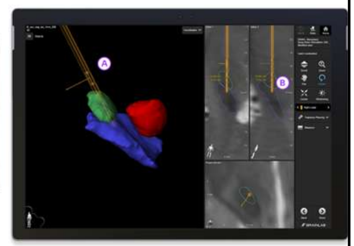
Lead Placement: Verification Imaging





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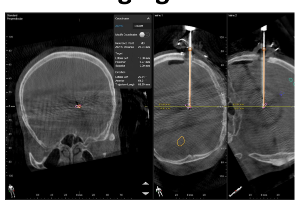
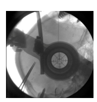
Lead Placement Verification: Imaging

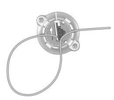
- Final Lead localization
  - Fluoroscopy
  - **Intraoperative CT**
  - Intraoperative MRI
- Lead is secured at the burr hole according to manufacturer instructions

TIP

- Use fluoroscopy during anchoring process to ensure no lead pull-out







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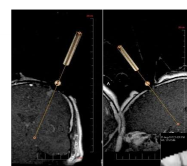
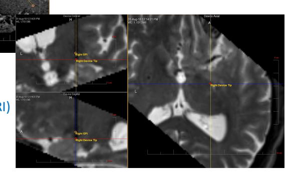
Lead Placement: MRI-guidance

Depending on your institution's current work flow and equipment availability

- Fluoroscopy
- Intraoperative CT
- **Intraoperative MRI**



Lead placement under direct visualization



Acquisition of real time imaging (e.g. intra-operative MRI) allow for ***image assisted lead placement guidance***. This approach can compensate for brain shift that can occur during the procedure.

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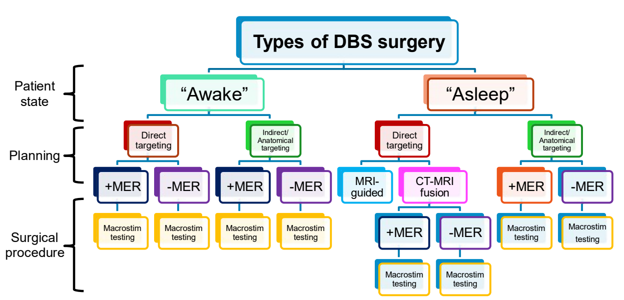

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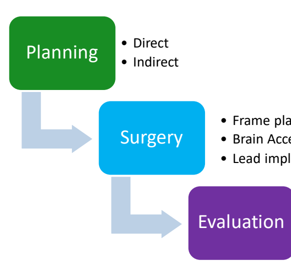
Workflow and Tips: "Awake" surgery



- Planning
  - Direct
  - Indirect
- Surgery
  - Frame placement
  - Brain Access
  - Lead implantation
- Evaluation
  - Imaging
  - Physiology
  - Test stimulation
  - Quality control

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Workflow and Tips: "Asleep" CT or MR-guided surgery

Planning
- Direct

Surgery
- Frame placement
- Brain Access
- Lead implantation

Evaluation
- Imaging

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Surgical steps

- Mark entry point
- Mount the Smart Frame
- Refine target
- Align to target
- Insert stylet
- Insert DBS electrode
- Real-time imaging to assess accuracy

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Tunneling Extension Wires and IPG

- Second stage of procedure is performed under general anesthetic
- Position patient to allow for ease of tunneling from rostral skin incision to caudal sub-clavicular subcutaneous pocket for IPG
- Consider intra-operative impedance checks on IPG to verify connections
- Great care must be taken to avoid damage to the DBS leads and/or extension wires and/or IPG

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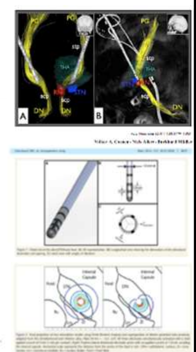
Current and Future Developments that may mitigate complications

- Novel imaging techniques (DTI)
- More efficient work flows that decreases electrode placement time
- Low profile devices
- Antibiotic cages
- Directional electrodes
- Closed loop stimulation paradigms



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Conclusions

- Meticulous planning and operative technique mitigate perioperative and late complications
- Diagnosis and management of surgical complications should be efficient, team based and definitive
- DBS teams should continuously review local processes to improve efficiency and accuracy of their DBS team – an active not a reactive process

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