Initial DBS Programming and Troubleshooting
Agenda

• Basics of the DBS System
• Know your target anatomy
• Initial and follow-up programming
• Cases and Troubleshooting
Basics of the DBS System
The negative electrode exerts the therapeutic effect.

Unipolar

Pulse Width
(µsec)
duration of each stimulus

Rate
(Hertz)
number of pulses per second

Amplitude
intensity of stimulation

* The negative electrode exerts the therapeutic effect
## Currently Available DBS Systems in US - Know your System

<table>
<thead>
<tr>
<th></th>
<th>Medtronic</th>
<th>Abbott</th>
<th>Boston Scientific</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IPG type</strong></td>
<td>Percept</td>
<td>Activa RC 5 and 7</td>
<td>Vercise Gevia</td>
</tr>
<tr>
<td></td>
<td>Activa PC (to be dc’d April 2021)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>33cc</td>
<td>22cc</td>
<td>33cc</td>
</tr>
<tr>
<td></td>
<td>39cc</td>
<td>30.4cc and 38.6cc</td>
<td>19.8cc</td>
</tr>
<tr>
<td><strong>Battery life</strong></td>
<td>&gt;5 years</td>
<td>3-5 years</td>
<td>3-5 years</td>
</tr>
<tr>
<td></td>
<td>15 years</td>
<td>3 years (5)</td>
<td>Rechargeable 15+ years</td>
</tr>
<tr>
<td></td>
<td>5-7 years (7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Constant Current</strong></td>
<td>Yes – single source</td>
<td>Yes – single source</td>
<td>Yes - MICC</td>
</tr>
<tr>
<td></td>
<td>Yes – single source</td>
<td>Yes – single source</td>
<td>Yes - MICC</td>
</tr>
<tr>
<td><strong>Multiple independent current sources</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Directional lead</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>BrainSense technology</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>MRI eligible</strong></td>
<td>Yes (3T) DBS ON in bipolar mode during exam</td>
<td>Yes (1.5T) DBS ON in bipolar mode during exam</td>
<td>Yes (1.5T) Device in MRI mode = turns OFF stim</td>
</tr>
<tr>
<td></td>
<td>Yes (1.5T) DBS ON in bipolar mode during exam</td>
<td>Yes (1.5T) Device in MRI mode = very low dose</td>
<td>No</td>
</tr>
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</table>
DBS Leads

- Medtronic cylindrical contacts on lead
- Abbott and Boston Scientific have directional leads
  - Allows for ring mode or horizontal current steering
Traditional DBS Programming Configurations
Contact Polarity

(a) Unipolar / Monopolar
(b) Bipolar
(c) Multipolar

Adjusting electrical parameters determines the size/intensity of the field

- **Rate (Hertz)**: number of pulses per second
- **Pulse Width (μsec)**: duration of each stimulus
- **Amplitude (Volts or mA)**: intensity of stimulation

**Secondary parameter contributing to total charge density**

- ↑ PW increases chance of depolarization → activate additional elements
- ↓ PW widens therapeutic window

**The main parameter used to control the intensity of stimulation**

- ↑ amplitude → ↑ field of stimulation

Rates between 135-185 Hz seem to exert similar clinical effects

- ↑ Freq may be particularly helpful in managing tremor
- ↓ Freq may be important in reducing stimulation side effects
Adjusting Parameters = Different Effects

Adverse events attributed to stimulating structures outside of the intended target

Strategy: choose the lowest stim parameters that produce maximal benefit and minimal adverse effects

## Typical Stimulation Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>STN</th>
<th>GPi</th>
<th>VIM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplitude</td>
<td>1.0 – 4.0 V/mA</td>
<td>1.0 – 4.0 V/mA</td>
<td>1.0 – 4.0 V/mA</td>
</tr>
<tr>
<td>Pulse Width</td>
<td>30 - 90 µsec</td>
<td>60 -120 µsec</td>
<td>60 -120 µsec</td>
</tr>
<tr>
<td>Rate</td>
<td>90 – 185 Hz</td>
<td>60 – 185 Hz</td>
<td>130 – 185 Hz</td>
</tr>
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</table>
Current steering with Directional Leads

- Activation of cathode steers the electric field towards the target of interest
- Deactivation of a segment that may be inducing adverse effects
- Especially useful for stimulation of small nuclei
- Suboptimally placed electrodes
Impact of Single Segment, Two Segment and Three Segment Activation on VTA Laterality

Know your Target Anatomy
# Regions of Interest

<table>
<thead>
<tr>
<th>Target region</th>
<th>Dorsolateral STN</th>
<th>Posteroventral GPi</th>
<th>ViM Thalamus</th>
</tr>
</thead>
</table>
| **Potential side effects** | • Capsular effects  
• Diplopia/oculomotor disturbance  
• Affective changes  
• Paresthesias  
• Dyskinesia induction | • Capsular effects  
• Visual phenomena  
• Gradient:  
  • Ventral – dyskinesia relief  
  • Dorsal – akinesia relief | • Paresthesias  
• Dysarthria  
• Tonic contractions  
• No effect |
| **Disease states** | PD  
Dystonia | PD  
Dystonia other hyperkinetic | Tremor  
Dystonia? PD? |
Current Steering in STN

Initial and Follow-up Programming
Initial Programming

• Goal
  • Select the best region (electrode/area) to stimulate that provides the most benefit without side effects

• Strategies
  • Test all electrode combinations – no!
  • Survey the lead- monopolar review
  • Any helpful intraoperative information?
  • Check lead location on post-op imaging?
  • Any LFP information available? (high beta in STN?)
Initial Programming Sessions

• First programming session = “monopolar review”
  • Set constant Freq (130Hz) and PW (60–90usec)
  • Assess the amplitude threshold for clinical benefits
    and side effects for each of the contacts (therapeutic
    window)
    - Ring mode
    - Single segment activation (directional leads)
  • Goal is to select the best contact for chronic
    stimulation
  • Reference for future adjustments and troubleshooting

• Step size
  • Ring mode: 0.5V/mA
  • Single segment: 0.25mA

• Alternate strategy for MICC: “beam” approach
Visual programming to guide contact selection

- Patient-specific reconstruction of DBS leads based on MRI and post-operative CT imaging, the reconstruction of nuclei and fiber tracts adjacent to stimulation sites
- CAUTION regarding inaccuracies of VTA models → cannot rely on images alone
Selection of optimal programming contacts based on local field potential recordings from STN in PD


The bipolar derivation demonstrating peak β-band activity (E0E1; solid blue line) corresponds to the electrode contact pair associated with optimal benefit during programming (contact pair 0 and 1).
Example of brainsense survey – localization of high beta peak
DBS Programming Pointers

Timing

- Initial programming 2-4 weeks following last brain surgery
  - Allows for resolution of microlesion effect
- Optimization period up to 6 mos, depending on indication
  - Frequency of visits at discretion of clinician

Things you will need:

- Clinician programmer
  - Be familiar with the system you are using
  - Learn buttonology
  - Learn connection issues
- Documentation strategy
  - Pen/paper
  - Informity®
  - Other
- Room for the patient to walk around
- Be observant
- Be patient
Impedance check - make sure electrically all well
Examples of Programming Forms

<table>
<thead>
<tr>
<th>Left Brain/Right Body</th>
<th>Right Brain/Left Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contacts:</td>
<td>Contacts:</td>
</tr>
<tr>
<td>Voltage:</td>
<td>Voltage:</td>
</tr>
<tr>
<td>Pulse Width:</td>
<td>Pulse Width:</td>
</tr>
<tr>
<td>Frequency:</td>
<td>Frequency:</td>
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<tr>
<td>Max Limit:</td>
<td>Max Limit:</td>
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<tr>
<td>Min Limit:</td>
<td>Min Limit:</td>
</tr>
<tr>
<td>Voltage:</td>
<td>Voltage:</td>
</tr>
<tr>
<td>Adjustable Variable:</td>
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<tr>
<td>Voltage:</td>
<td>Voltage:</td>
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<tr>
<td>Adjustable Variable:</td>
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Groups Form
Documentation for Directional Leads

[Diagram showing directional leads and stimulation data]

<table>
<thead>
<tr>
<th>Sort By: Power</th>
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<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>3C</td>
</tr>
<tr>
<td>3B</td>
</tr>
<tr>
<td>3ABC</td>
</tr>
<tr>
<td>3A</td>
</tr>
<tr>
<td>2ABC</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>1</td>
</tr>
</tbody>
</table>
Follow-up programming

- **Look** at what was done at last programming session
  - Programming + medication changes
  - Was desired effect achieved?

- **Assess** interim changes/new symptoms
  - Is there adequate control of disease related symptoms/features?

- **Decide** if there is a need for DBS adjustment
  - Is this a stimulation-related issue?
  - Is this a medication management issue?
  - Is this disease progression?

- **Formulate** management strategy

- **Check** hardware integrity – impedance, battery status, charging
Cases & Troubleshooting
Case: Stimulation side effects

- 61yo male with PD with STN DBS
- Developed left facial pulling, dysarthria, left arm tonic contractions when placed into the following settings

- DBS settings: R STN C+0-, 1.8V, 60us, 130 hz

What is happening?

What should you do?
Poll question #1

• What would you do first?
  1) Turn off the DBS and see what happens
  2) Lower stimulation amplitude and observe effect on symptoms
  3) Adjust some other DBS parameters
  4) Order an MRI brain
  5) Find an attending and ask for help
Spread of current to internal capsule

- Lower thresholds right after surgery
- Can occur with STN, GPi, VIM Targets
  - STN - lead too lateral and/or anterior
  - GPi - lead too posterior or too medial
  - VIM - lead too lateral

- Programming strategies
  - Bipolar stimulation
  - Try other contacts
  - Current steering
  - Reduce pulse width

- Image brain to assess lead location, migration
  - May need lead revision
Case: Stimulation induced dyskinesia– motor side effects

• 58 yr old male with PD and STN DBS surgery 3 weeks ago, developed dyskinesia after initial DBS programming.
  • Left STN: C+1-, 2.0mA, 60us, 130 hz
  • Right STN: C+9-, 2.0mA, 60us, 130 hz

• Medications:
  • Carbidopa/levodopa 25/100 2 tabs 5 X day
  • Entacapone 200mg tabs 5 X day
  • Pramipexole 1mg TID
  • Rasagiline 1.0mg QD

• What would you do?
Poll question #2

• How would you first approach management of this situation?
  1) Turn off DBS
  2) Lower DBS on both hemispheres to 1.0mA
  3) Leave DBS alone and cut down PD medications
  4) Add a more superior contact on both the left and right leads
  5) Find and attending and ask for help
Stimulation Induced Dyskinesia

• Most common with STN stimulation (possible with GPe)
• If it occurs – indicates you are in motor STN
• Can occur acutely with programming or can be delayed (hrs)
• In PD - reduce PD meds (10-50%)

• Programming strategies
  • If severe, turn off DBS
  • Start low and slowly increase voltage or amplitude (days to weeks, pt control)
  • Consider bipolar stimulation, lower pulse width (weaken/restrict field)
  • Consider adding dorsal contact (ZI stim may help suppress dyskinesia)
  • Consider interleaving function, current steering (focus stim)
Poll question #3
Case: Freezing and Postural Instability

• How would you interpret this situation?
  1) The patient is undermedicated
  2) The patient is understimulated
  3) The patient is overstimulated
  4) This is disease progression
Assessment of worsened gait freezing in PD

• On or off symptom?
• Unilateral or bilateral?
• Review medications – adjust?
• Consider increasing stim?
• If GPI, consider more dorsal contact
• R/o slight spread to internal capsule
• PT/Fall precautions
Case: 70yo F with long-standing ET who had failed multiple medications underwent bilat ViM DBS

• Right hand: expected improvement at minimal settings of the left ViM electrode in monopolar configuration.
• Left hand: initial good tremor suppression, also in monopolar configuration
• During subsequent sessions, the patient started noticing loss of sufficient tremor control in the left hand (habituation) along with side effects from higher stimulation settings.
Poll question #4

• What would you do?
  1) Check for an open circuit
  2) Keep ramping up stim
  3) Change contact
  4) Turn stim off at night
  5) Give different group settings
  6) Get a brain MRI
Repeated adjustments to Right ViM stimulation parameters

- Monopolar, bipolar, interleaved configurations
- Could not tolerate turning stimulator off at night due to marked rebound
- Transient benefit only, followed by return of symptoms to their previous severity within days or weeks.

<table>
<thead>
<tr>
<th>Rt ViM settings</th>
<th>Polarity</th>
<th>Amplitude (V)</th>
<th>Pulse width (μsec)</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st programming session</td>
<td>C+10-</td>
<td>1.0</td>
<td>60</td>
<td>130</td>
</tr>
<tr>
<td>Maximum monopolar settings</td>
<td>C+10-</td>
<td>2.2</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Maximum bipolar configuration</td>
<td>9+10-</td>
<td>2.5</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>Maximum interleaved configuration</td>
<td>ViM1 C+10-</td>
<td>3.0</td>
<td></td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>ViM2 C+9-</td>
<td>2.6</td>
<td>60</td>
<td>125</td>
</tr>
<tr>
<td>OFF</td>
<td></td>
<td></td>
<td></td>
<td>Marked left hand rebound tremor with a rest component, which then subsided and was followed by prominent left hand postural and kinetic tremor with almost the same severity as her pre-op tremor.</td>
</tr>
</tbody>
</table>
What would you do next?

• Head CT with thin cuts to check for electrode placement, which was merged back to the pre-op MRI using the StealthStation Surgical Navigation System
  • → Suboptimal right VIM lead positioning
    • Approximately 2 mm anteromedial from the optimal location
    • Left VIM accurately placed

• Recommendation?
  • Revision of the right VIM electrode
<table>
<thead>
<tr>
<th></th>
<th>AFTER REVISION of left ViM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st programming session</td>
<td>C+10-</td>
</tr>
<tr>
<td>9 months</td>
<td>C+10-</td>
</tr>
</tbody>
</table>
Troubleshooting DBS: Summary

- **Interrogate IPG**
  - Not transmitting, long history of use
    - Battery is dead
  - Transmitting OK
    - Is output ON?
      - No
        - Turn it on
      - Yes
        - Check for open circuit
          - Open circuit
            - Plain X-ray for lead fracture
          - Electrical system OK
            - Check stimulation-induced side effects
              - Low voltage side effects or no side effects
                - Brain MRI or CT for lead location
              - Location-appropriate side effects
                - Reconsider patient’s diagnosis
UCSF Movement Disorders Team

**Neurosurgery**
Philip Starr, MD, PhD
Paul S. Larson, MD
Doris Wang, MD, PhD
Daniel Lim, MD, PhD
Ro‘ee Gilron, PhD
Juan Anso Romero, PhD
Robert Wilt

**Neuropsychology**
Caroline Racine Belkoura, PhD

**Nursing**
Monica Volz, FNP, MS
Susan Heth, MS, RN
Gina Bringas-Cinco, RN
Annie Li Wong, NP
Rigzin Lama, RN

**Fellows**
Amir Badiei, MD
Prarthana Prakash, MD
Mia Vuong, MD
Lauren Hammer, MD, PhD
Meredith Bock, MD
Kat Wong, MD

**Research /Administrative**
Sarah Wang, PhD
Janet Allen
Kathleen Comyns, MPH
Cheryl Meng, MPH
Farah Kauser, PhD
Danilo Romero
Emerald Mann
Jacque Perkins
Primi Ranola
Vy Nguyen
Raisa Syed
Aaron Daley

**Clinical Staff**
Yasmeen Gonzalez
Christine Jiunti
Jeverly Calaunan
Darel Obonna
Maria Loutlette Bautista
Samuel Yee
Judith Long

**Neurology**
Jill Ostrem, MD
Caroline Tanner, MD, PhD
Marta San Luciano, MD
Nicholas Galifianakis, MD
Maya Katz, MD
Ian Bledsoe, MD, MS
James Maas, MD, PHD
Chadwick Christine, MD
Michael Aminoff, MD
Robert Edwards, MD, PhD
Ken Nakamura, MD, PhD
Alexandra Nelson, MD, PhD
Michael Geschwind, MD, PhD
Cameron Dietiker, MD
Nijee Luthra, MD, PhD
Ethan Brown, MD
Samuel Goldman, MD
Simon Little, MD, PhD
Rafael Zuzuarregui, MD

**Psychiatry**
Andrea Seritan, MD

**Physical Therapy**
Heather Bhide, PT