Deep Brain Stimulation (DBS) for Parkinson's Disease

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Objectives:
- Brief history of DBS
- DBS for PD
- Coming advances in DBS

Brain Stimulation Offers
- A new era for the neurosurgical treatment of neurological disorders
- To improve quality of life
- Offer hope for medically intractable patients
History of Brain Stimulation

- Scribonius Largus
- Ancient Rome
- Electrical catfish in the treatment of facial neuralgia

Modern Era of Brain Stimulation

- J. L. Pool  Columbia University
  - 1948 - A silver electrode placed into the caudate nucleus by open craniotomy
  - Severe depression secondary to advanced Parkinson’s disease and connected it to an implanted induction coil.

- Benabid – France
  - 1987 – Vim stimulation for essential tremor
  - 1993 – STN stimulation for PD
Deep Brain Stimulation for Movement Disorders:

<table>
<thead>
<tr>
<th>Lesions</th>
<th>DBS</th>
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</thead>
</table>
| Advantages | • Permanent  
            • No hardware maintenance |
| Disadvantages | • Permanent  
                        • Cannot be modulated according to effect |
| | • Reversible  
            • Modulation along time  
            • More aggressive treatment in more difficult targets  
            • Implantable hardware  
            • Infection  
            • Dependency on a medical center |

Indications of DBS

• Movement disorders  
  – Parkinson’s disease  
  – Essential Tremors  
  – Dystonia  
  – Other  
• Chronic Pain  
• Psychiatric disorders  
  – Depression  
  – OCD  
  – Tourette’s syndrome  
• TBI
Parkinson’s Disease – Most Common Indication for DBS

DBS for Movement Disorders: Neural circuitry

NORMAL

PD

GABA

Glutamate

Dopamine


DBS for Movement Disorders: Rationale for surgery

Parkinson's Disease
How?: The Multidisciplinary Approach

- Team of specialists
- Close collaboration is essential

- Neurosurgeon
- Neurologist
- Neurophysiology
- Neuro-radiology
- Psychiatry
- Neuropsychology
- Bioethics

How is it done? STN-DBS

Step 1: Surgical Candidates

- Cardinal Symptoms
  - Tremor, rigidity, akinesia/bradykinesia, freezing of gait
- Medical therapy "maxed out"
  - Motor (ON/OFF) fluctuations
  - Drug-induced dyskinesias
- L-DOPA response
- Age & health
- Rule out Parkinson’s-Plus syndromes
- Rule out psychiatric illness
STN-DBS: Surgical Candidates

- Neuropsychological clearance
  - No significant cognitive deficits, dementia
- MRI: no structural lesion/significant atrophy
- PET/MRI: Not necessary for clinical care, investigational
- DAT: not essential; helpful in distinguishing ET from PD

- Education of patient and family
  - Realistic expectations
  - Surgery is not a cure → disease progression

Goals:
1. Complication Avoidance
2. Location
3. Location
4. Location

If Location is excellent, stimulation is excellent
If Location is good, stimulation is good
If Location is poor, stimulation is poor
Stereotactic localization:
Hardware
Frameless stereotaxy

Stereotactic localization:
Software

Stereotactic localization:
Targeting

• Anatomic
  – Indirect
  – Direct
• Physiologic
  – MER
Indirect: Target based on AC-PC

- Midcommissural point
- 11-13 lateral
- 3-4 mm posterior to MCP
- 3-5 mm below MCP
- Target = bottom of the nucleus

Targeting based on atlas

Direct targeting
Surgical Procedure

- Stereotactic frame fixed to table
- Burr hole placement
  - Allows visualization of cortical vessels
  - Makes multiple pathways for MER possible
  - Must accommodate anchoring device

Microelectrode recording

- Several strategies

- One electrode / two electrodes/ five electrodes

- Criterion for implantation
  - Acceptable length
  - Border mapping
  - Combination of strategies: consider
    - Risk of each penetration
    - Patient tolerance and compliance
Intraoperative Mapping

Reticular / Anterior Thalamus

Typically two cell types:
- **Tonic / Irregular**
  - Rate = 15 – 25 spikes/sec
- **Bursting**
  - Slow Rate (15 – 25 Hz)
  - w/ rapid bursts (> 300 sp/sec)
Zona Incerta / Fields of Forel

- Relatively quite region
- Consists of:
  - Thalamic fasciculus (H1)
  - Pallidofugal fibers
  - Cerebellothalamic fibers
  - Zona Incerta
  - Thin strip of gray matter
  - Variable recording pattern
  - Lenticular fasciculus (H2)
  - Pallidofugal fibers

Subthalamic Nucleus

- Marked by:
  - Irregular firing pattern
  - Increase in background cellular activity

Substantia Nigra pars reticulata

- Marked by:
  - Regular firing pattern
  - Higher mean rates than STN.
  - Rate = 60 – 80 Hz (Mean 71 Hz)
Surgical Procedure

Lead placement

- Leads placed in motor territory of nucleus
- May or may not be along same trajectory as MER penetration(s)
- Leads have four contacts
- Multiple electrode configurations possible with post-op programming

Macrostimulation: Too Anterior or Lateral

Internal Capsule effects
- Muscle contraction
- Speech
- Conjugate Eye deviation
Macro stimulation

Bipolar
High frequency
90 microseconds
Stepwise increase in amplitude
Effects
Thresholds

- Capsule: too lateral
  - Upper extremity, lower extremity, face and tongue
- III nerve
  - Too medial
- Paresthesias
  - Medial / posterior in dorsal contacts
  - Posterior in ventral contacts

Macrostimulation – Newer Features

- Intra-operative impedance testing
- Visualize rigidity, bradykinesia and tremor improvement with external pulse generator
- Assess electrode with both monopolar and bipolar stimulation

Macrostimulation: Too Medial

OFF Right STN  ON Right STN
Medial Lemniscal effects
- Paresthesias
- Transient
- Persist: too posterior or too deep, medial

Secure the electrode
**DBS Programming**
- Start programming 4 weeks after surgery
  - Cerebral edema
  - “Micro effect”
- No change in medications
- Gradually titrate stimulation up and medication down
- Labor intensive
  - Experience counts

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**Parkinson’s Disease : GPI stimulation**
- Parkinson’s Disease – levodopa dyskinesias
- Dystonia:
  - Primary
  - DYT1 +
  - Generalized

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**GPI - anatomy**
Unilateral GPi and unilateral STN are both effective for motor symptoms. There was a trend for more medication reduction with STN. Similar mood and cognitive effects.

Complications

<table>
<thead>
<tr>
<th>Study Complication</th>
<th>Beric et al</th>
<th>Kondziolka et al</th>
<th>Oh et al</th>
<th>Limousin et al</th>
<th>Lyons et al</th>
<th>CNRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of leads</td>
<td>150</td>
<td>66</td>
<td>150</td>
<td>170</td>
<td>150</td>
<td>155</td>
</tr>
<tr>
<td>Follow up time</td>
<td>3.5 yrs</td>
<td>30 mths</td>
<td>30 mths</td>
<td>2 yrs</td>
<td>3 yrs</td>
<td>7 yrs (mean 50 mths)</td>
</tr>
<tr>
<td>Hemorrhage (ICH) (per lead)</td>
<td>3.3% (per patient)</td>
<td>1.5% (per patient)</td>
<td>2.3%</td>
<td>2.2%</td>
<td>2.2%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Infection (per patient)</td>
<td>9.4%</td>
<td>18.2%</td>
<td>14%</td>
<td>NA</td>
<td>NA</td>
<td>24.1%</td>
</tr>
<tr>
<td>Hardware related complications (per patient)</td>
<td>5.4%</td>
<td>10.2%</td>
<td>14%</td>
<td>NA</td>
<td>NA</td>
<td>26.1%</td>
</tr>
</tbody>
</table>
What is new in DBS?

**DBS Methods**
- Frameless DBS
- MRI guided DBS
- Imaging

**DBS Devices**
- Directional leads
- Smaller IPG
  - Rechargeable
  - At burr hole
- Sensing features
- Improvements in output
  - Waveforms
- MRI safe devices
  - Shielding
  - Decoupling
- Local Field Potential

**DBS Indications**
- Epilepsy
- Depression
- Obsessive compulsive disorder
- Anxiety disorders
- Addictions
- Overeating
- Tourette's
- Chronic pain
- Headaches
- Stroke
- Tinnitus
- Traumatic brain injury
- Obesity
MR Guided DBS Placement
IMRIS is available at CCF
• Dystonia
• Patients requiring intubation

Patient-Specific DBS Model
Contact 0
Contact 2

Patient-Specific Parameter Selection
Directional Electrodes

Electrode Comparison

Current Design

Split Band
Directional Electrode

3 V Stimulation with 0.12 ms Pulse Durations
Electrode Designs

Current Design  Split Band Directional Electrode  3D Directional Electrode

Local Field Potential Sensing