



# Updates on DBS Programming: Image-guided programming and LFP-based programming

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**School for Device-Aided Therapies in  
Parkinson's Disease**

**Bangkok, Thailand | May 6-7, 2026**



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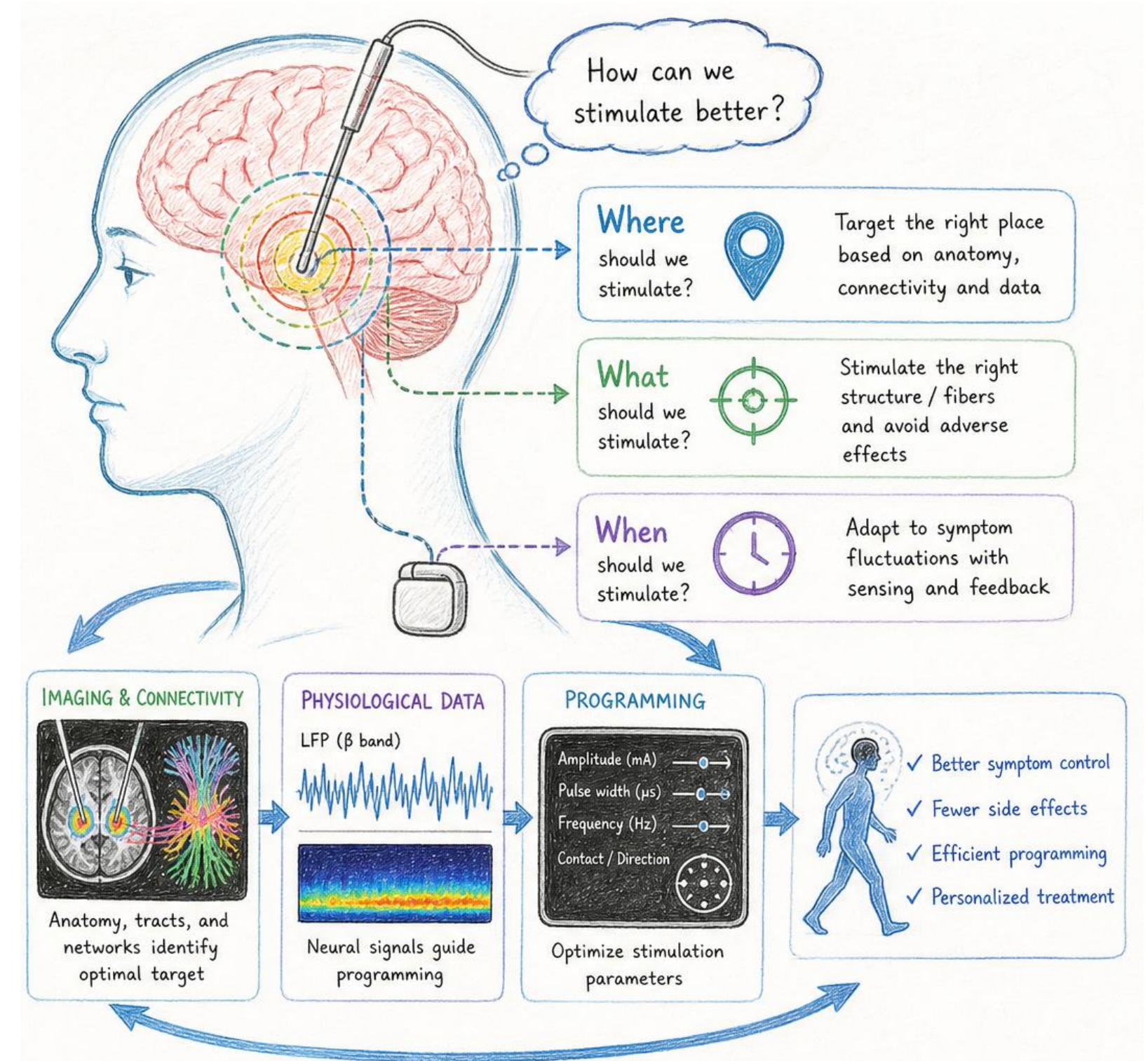
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## Outline

- Concept of DBS Programming
  - Where to stimulate?
  - What to stimulate?
  - When to stimulate?
- Image-guided Programming
  - Sweet spot analysis
  - Avoiding adverse effects
  - Clinical applications
- LFP-based Programming
  - Beta oscillations in Parkinson's disease
  - Sensing-based programming
  - Adaptive / closed-loop DBS



Generated by GenAi (Chat GPT)

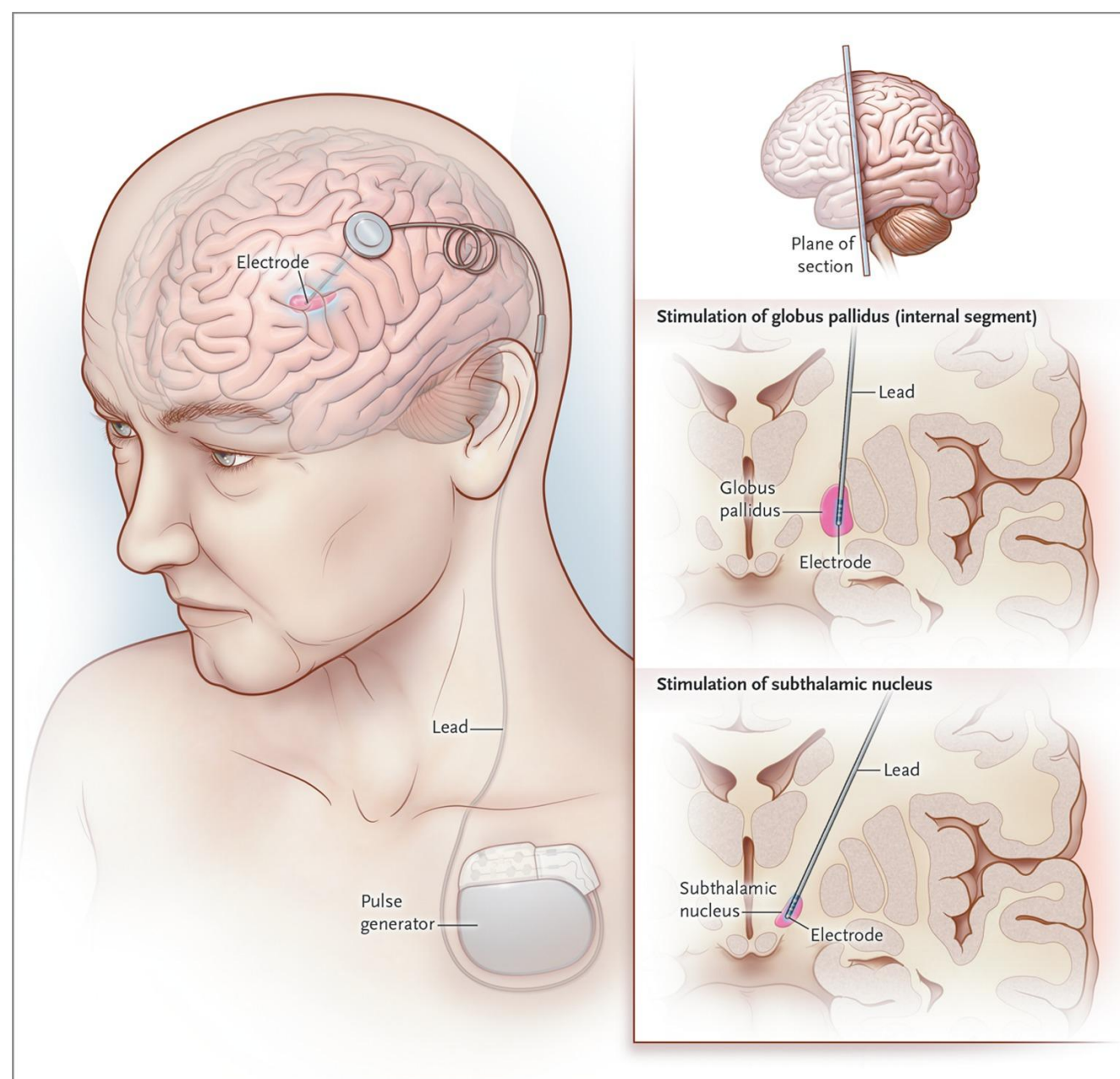
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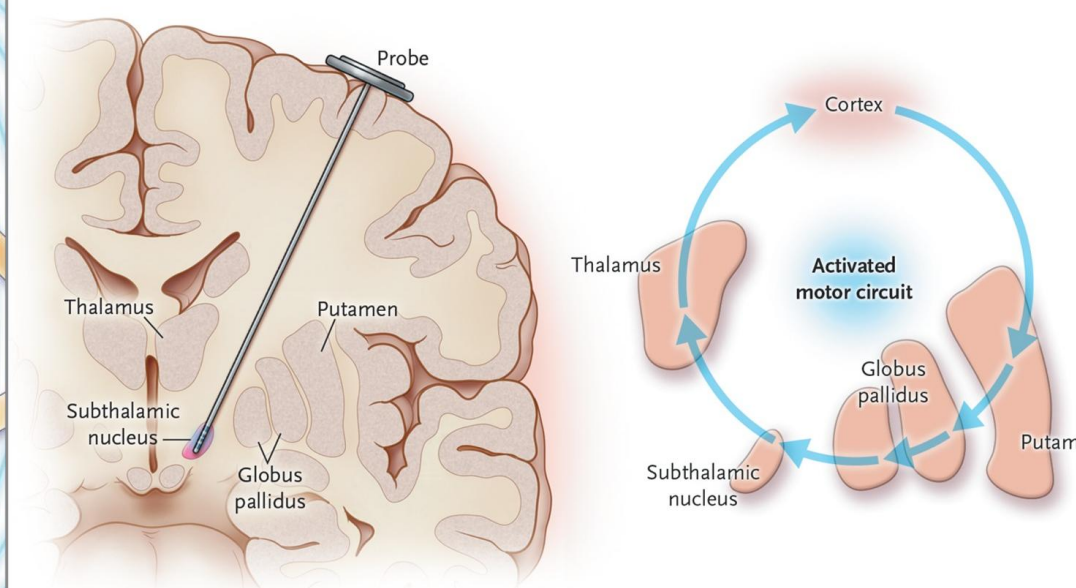
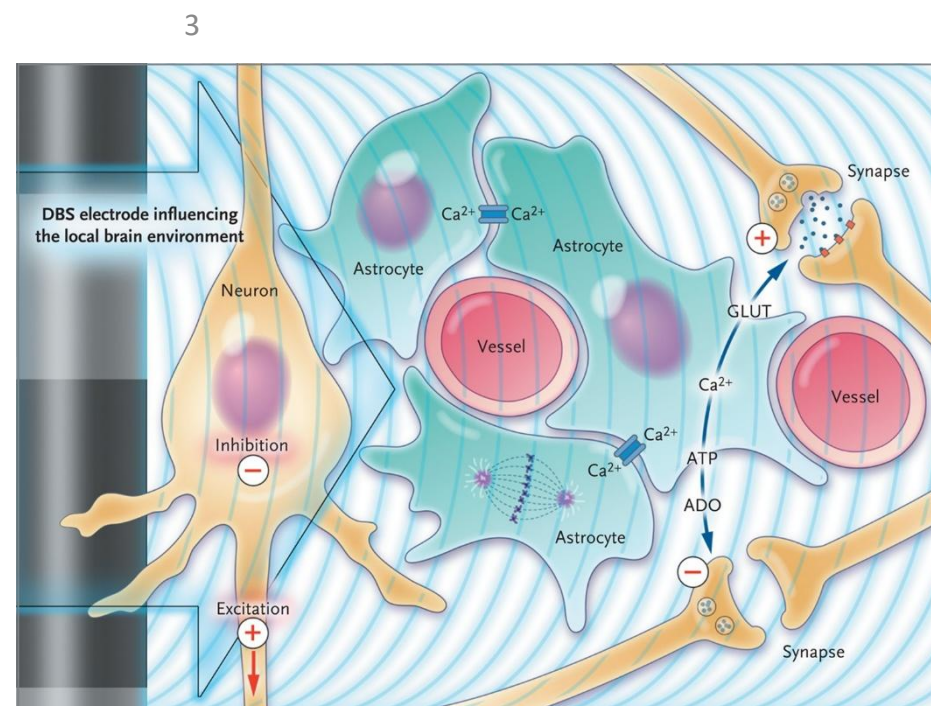


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## Deep Brain Stimulation



- Modulation of dysfunctional neural network by suppressing abnormal neural.
  - ✓ "circuitopathies"
- Multiple, time-dependent effects
  - ✓ Cellular → local circuits → large neural networks
- Modification of "electrical" neurotransmission



Lozano et al. Nat Rev Neurol, 2019

Okun et al. N Engl J Med 2012

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## What is ideal DBS stimulation program?

### Where should we stimulate?

- ✓ stimulating small target volume
- ✓ directional settings
- **Image guided or Sensing based assistance**

### What should we stimulate?

- ✓ stimulating axons which delivers benefit
- ✓ avoid current spreading to fibers or structures those evoke adverse effects
- ✓ eliminate the signals causing dysfunctions (oscillopathy)
- ✓ minimal effect for normal networks
- **Image guided or Sensing based assistance**

### When should we stimulate?

- ✓ avoid overstimulation
- ✓ Covering symptom fluctuations related to Levodopa
- **Adaptive settings / Closed loop settings**

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## Where to stimulate?

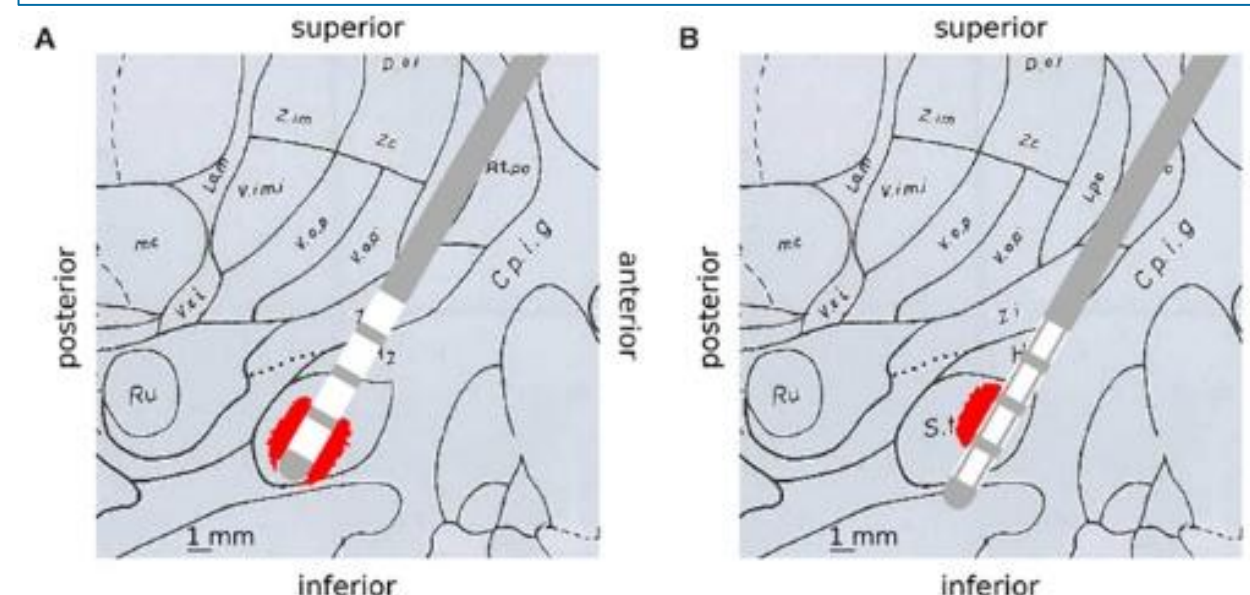
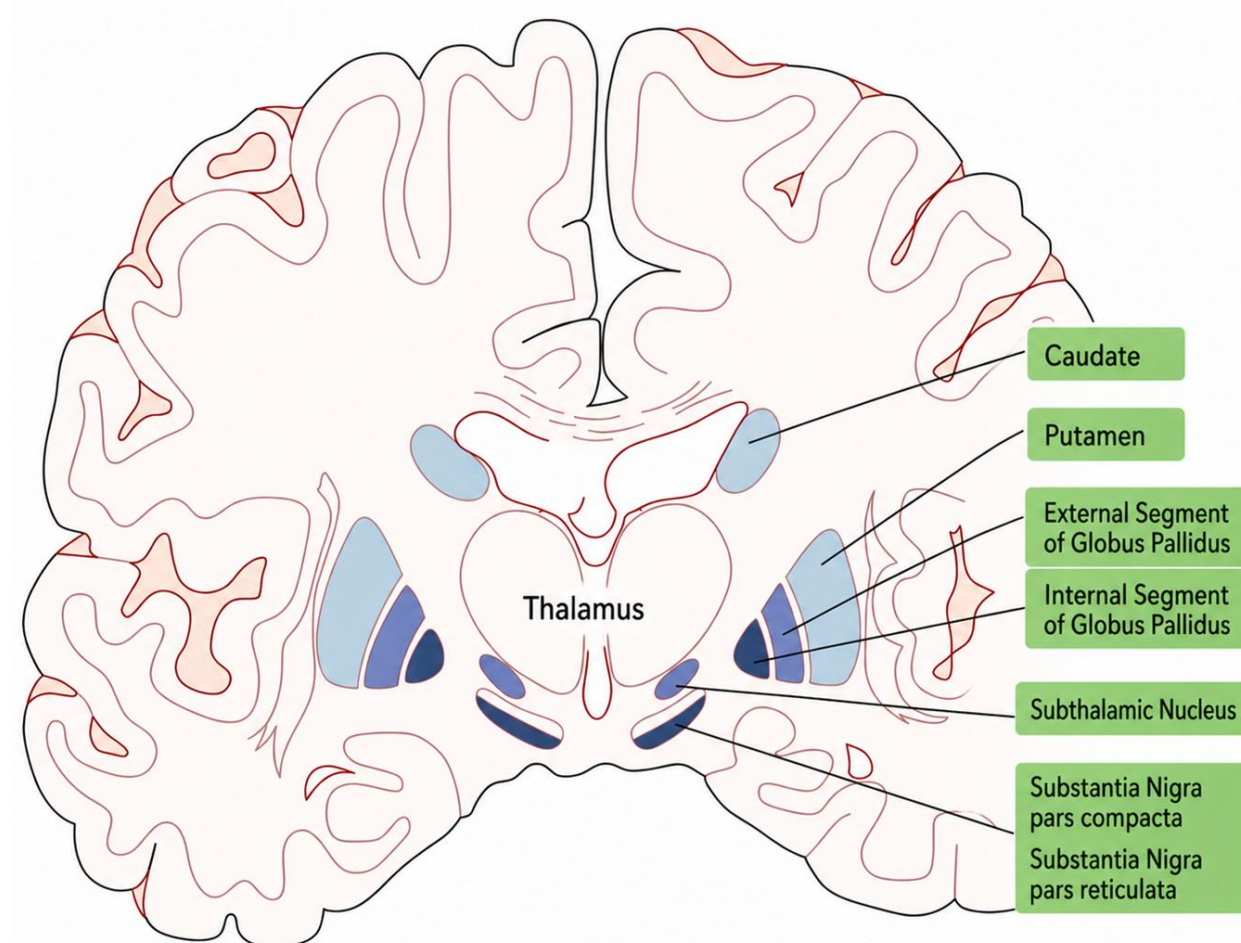
## Why stimulation-induced symptoms appear?

### STN

Small volume,  
about the size of adzuki bean

### DBS lead

1.3mm in diameter  
1.5mm length of contacts



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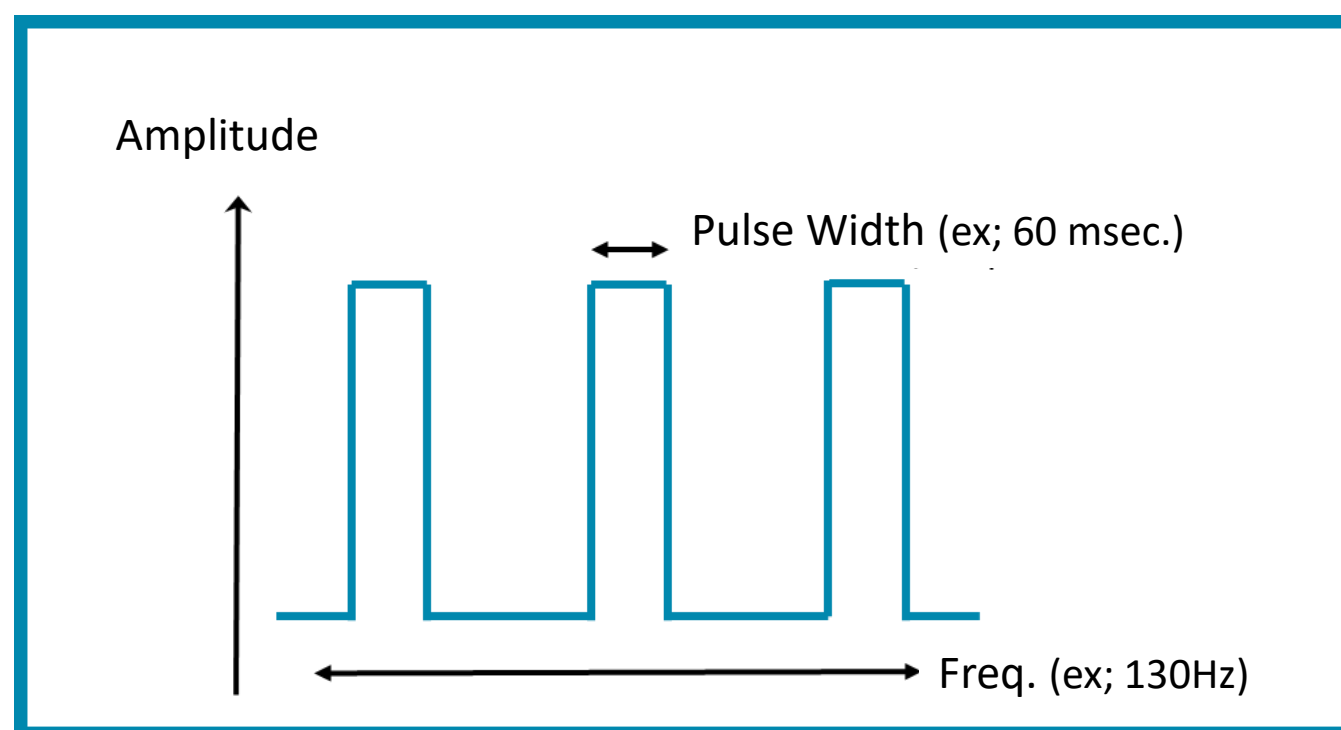
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## Where to stimulate?

What Determines the Volume of Tissue Activation?— Size and Shape

- size; volume of activated

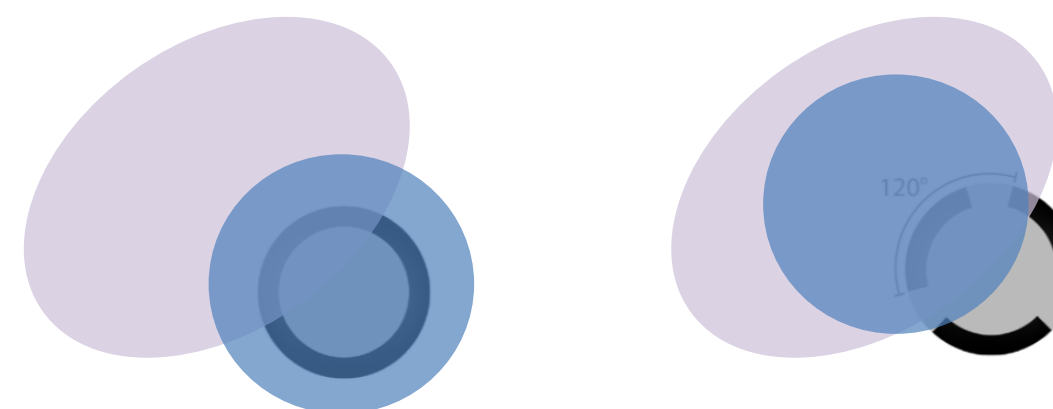
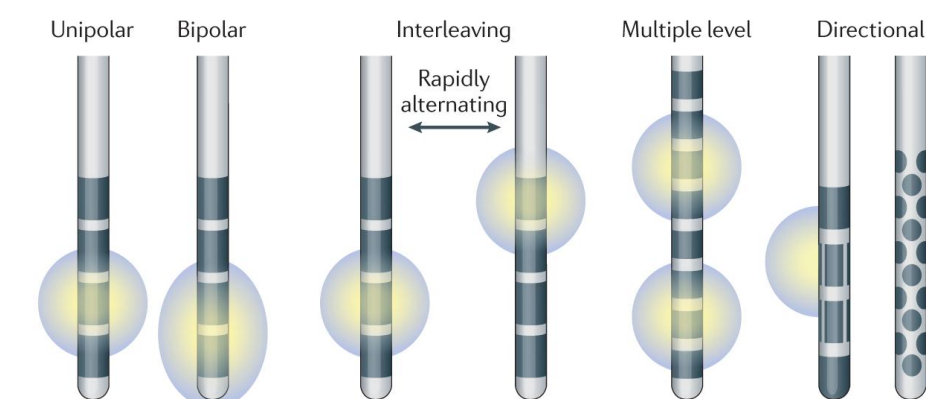
- Amplitude (mA)
- Pulse width (msec.)
- frequency (pps / Hz)



Scheme of stimulation

- shape

- electrode configuration
  - ✓ 0.5mm gap
  - ✓ 1.5mm gap
  - ✓ Directional lead
- polarity



Hickey et al. Front Neurosci 2016, Krauss et al. Nat Rev Neurol. 2020  
Steigerwald et al. Mov Disord 2016, Anderson et al. J Neural Eng. 2018

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## What to stimulate?

### Fibers with "effects"

- Pallido-subthalamic connections
- Pallido-thalamic connections
- Hyperdirect pathway

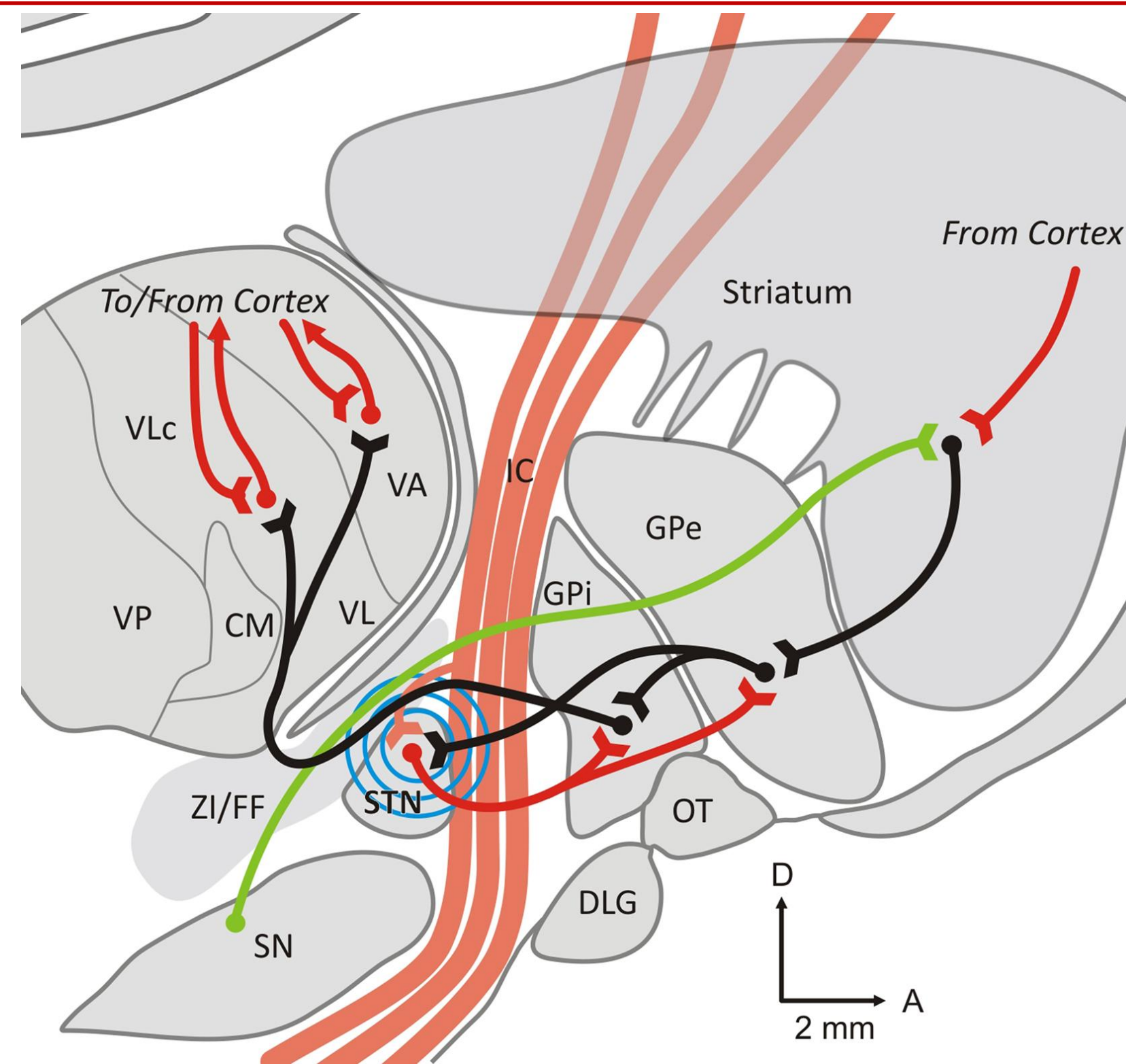
VS

### Fibers potentially evoke adverse effects

- Internal capsule
- Cerebello-thalamic tract

Devergnas et al. Front Syst Neurosci. 2011

## to prevent adverse events



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## STN

### and surrounding structures

lateral : internal capsule

→ twitching, dysarthria

medial : Medial Forebrain Bundle

→ Psychiatric, autonomic symptoms

anterior : internal capsule

→ twitching, dysarthria

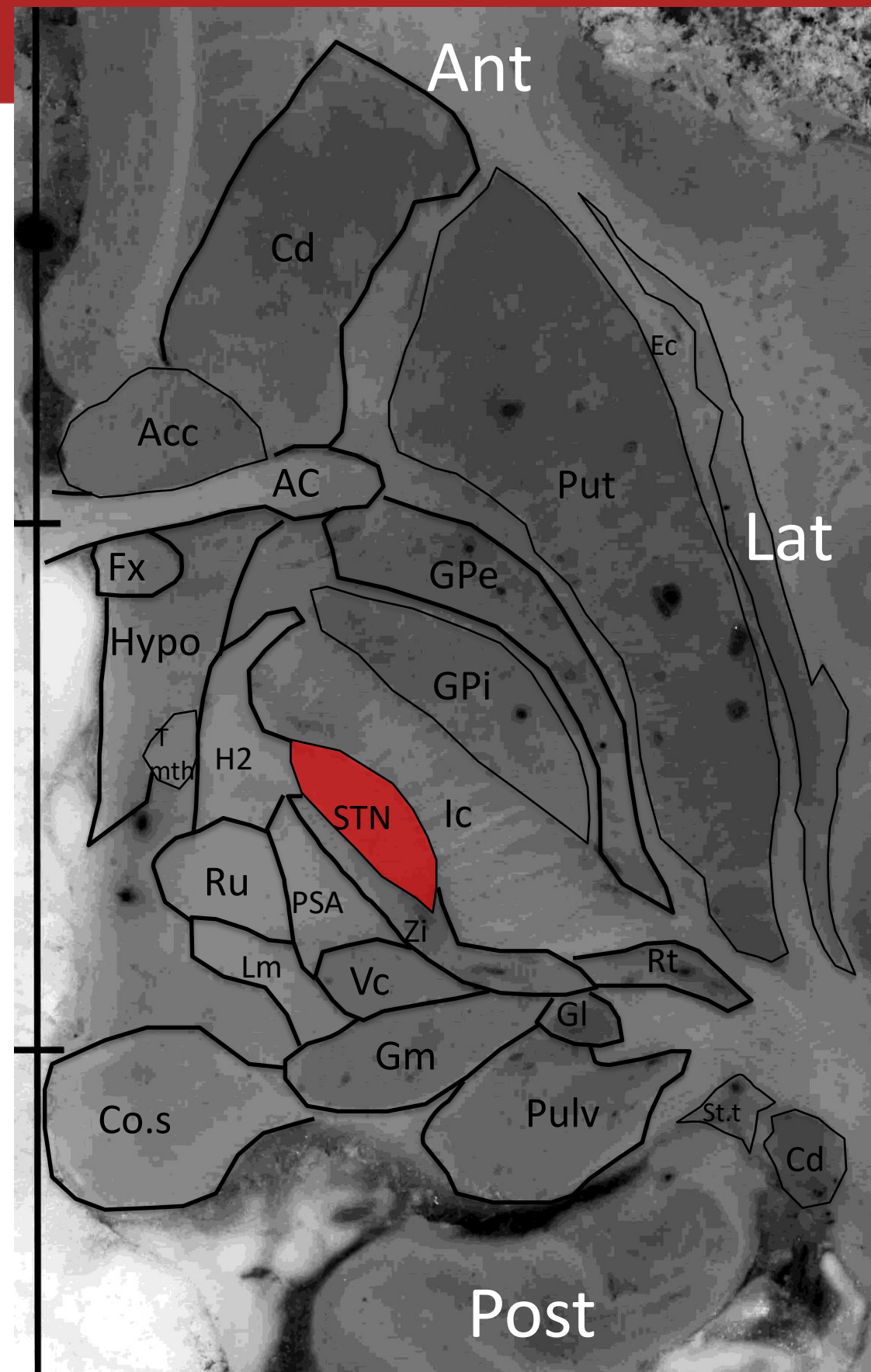
posterior : Vc, Medial Lemniscus

→ numbness

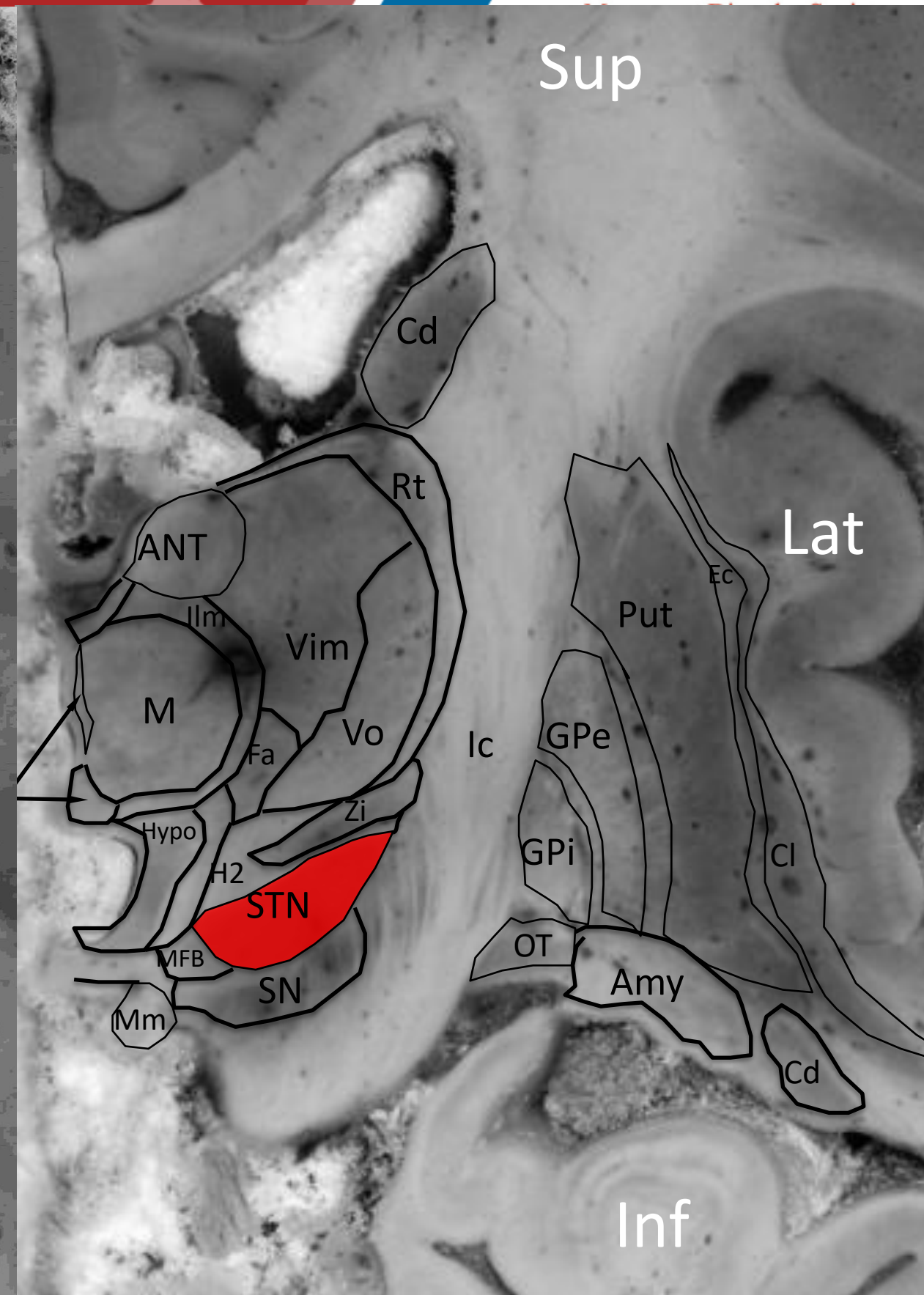
superior : H2 , Zi

inferior : Substantia Nigra

→ Psychiatric symptom acute depression



axial



coronal

Pathology by Dr. Kawasaki

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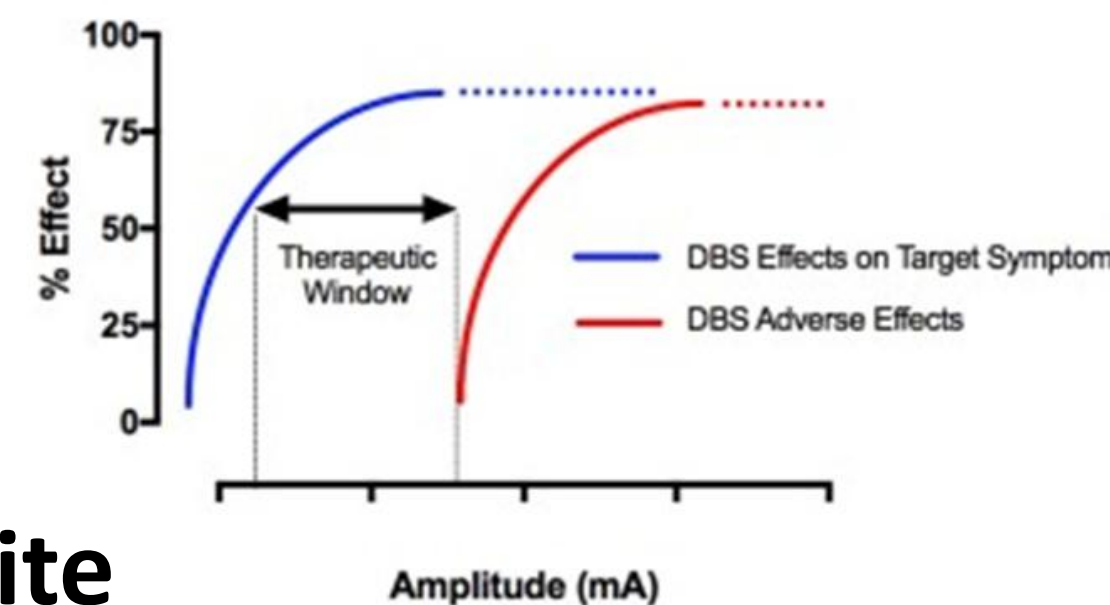


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✓ Identify the optimal stimulation site and develop a long-term treatment strategy

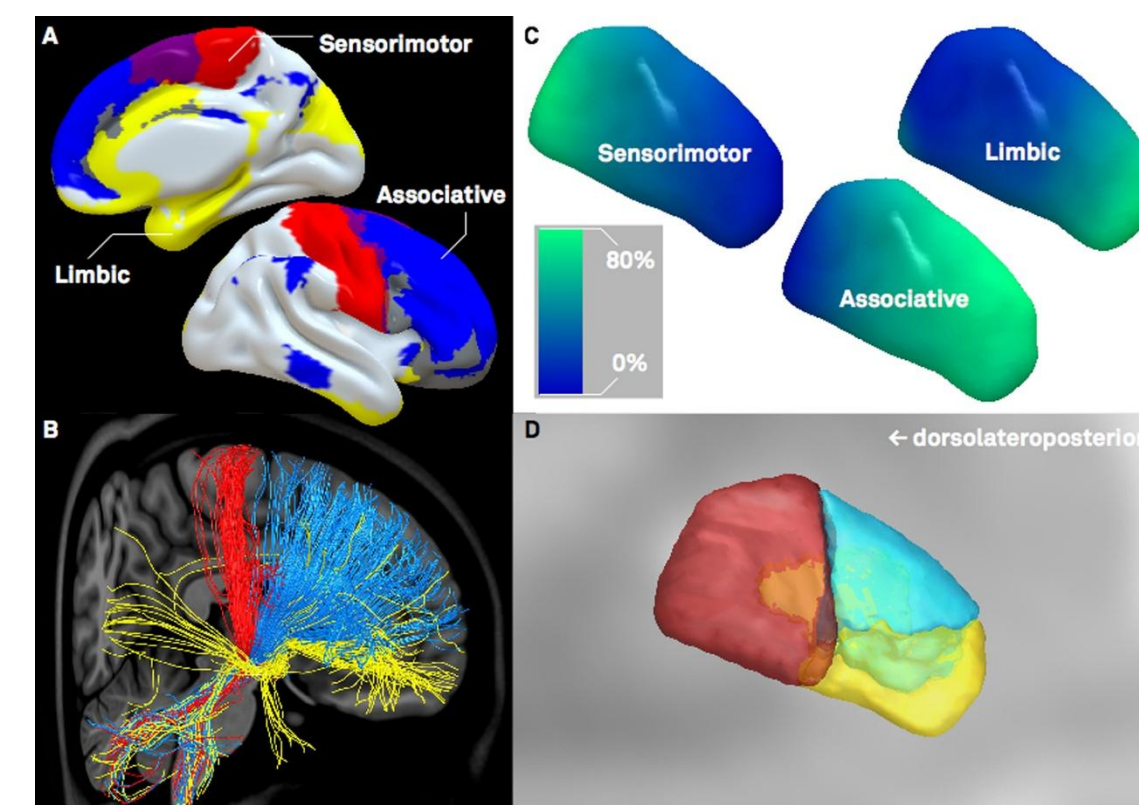
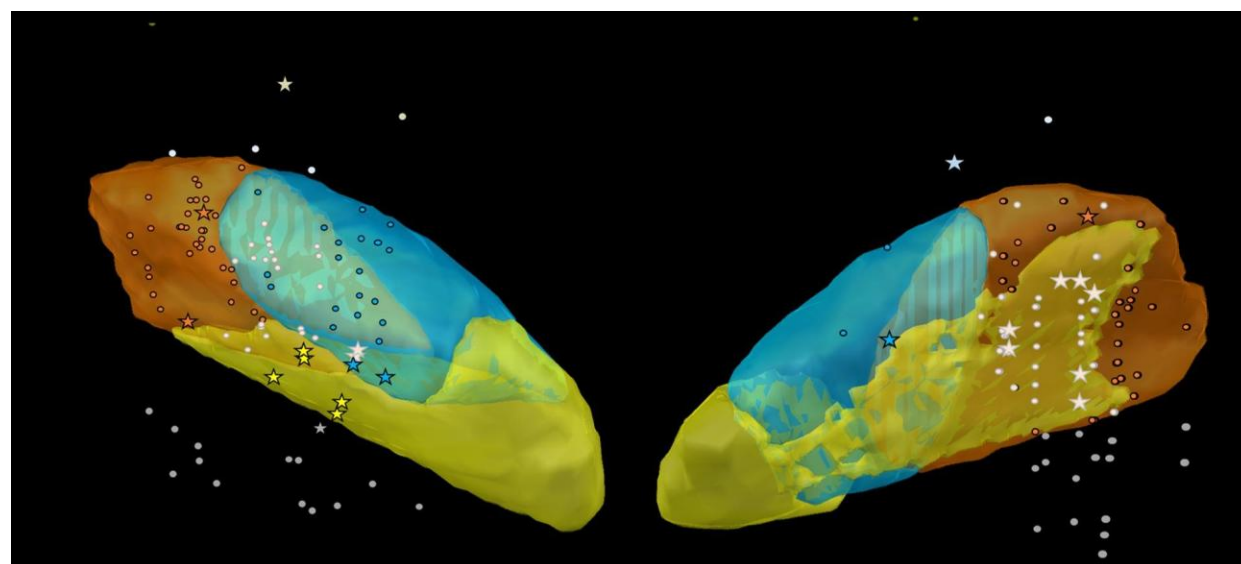
## ➤ Clinically optimal stimulation point

- Fine therapeutic effect at the lower current value
- No adverse effects up to the higher current value



## ➤ Anatomically / physiologically optimal stimulation site

- Image guided analysis or Sensing-based



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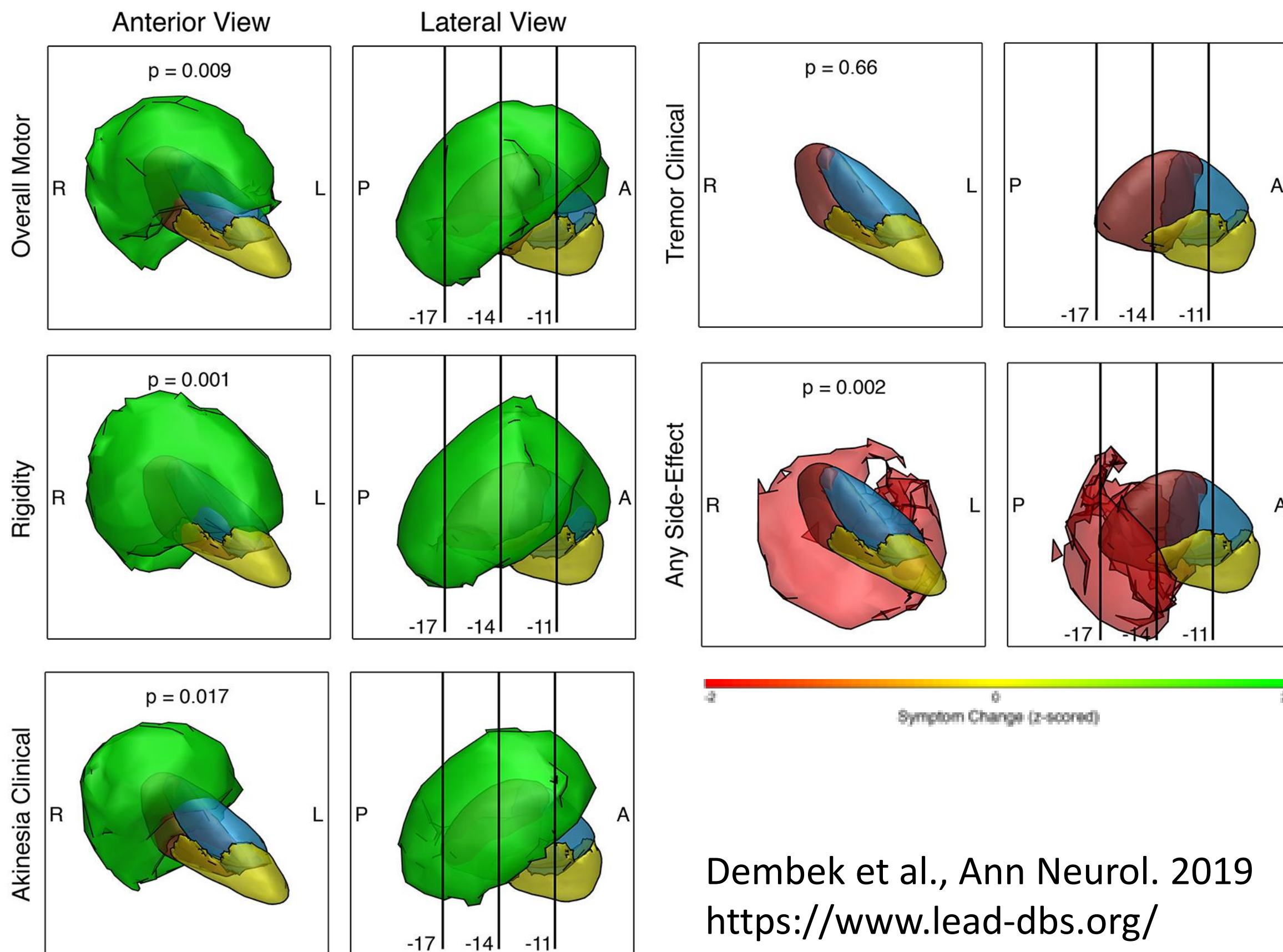


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## Searching best stimulating point by images

21 PD patients with STN-DBS  
449 stimulation settings analyzed

- ✓ Symptom-specific sweet spot analysis
- Sweet spot for akinesia located more posterior than rigidity
- No significant voxels for tremor due to limited sample size
- ✓ Implemented in the Lead-DBS toolbox



### STN Sweetspots (Dembek 2019)

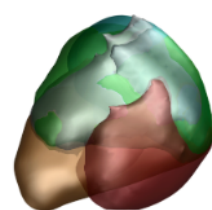
A set of probabilistic sweetspots based on 449 DBS settings in 21 PD patients which showed utility to predict variance in clinical outcomes following STN-DBS in out-of-sample data.

#### How to obtain the atlas:

- You can find more information about this atlas [here](#).
- The atlas is preinstalled within Lead-DBS.

#### Related citations:

- Dembek, T.A., Roediger, J., Horn, A., Reker, P., Oehr, C., Dafsari, H.S., Li, N., Kühn, A.A., Fink, G.R., Visser-Vandewalle, V., Barbe, M.T., Timmermann, L., 2019. Probabilistic Sweetspots Predict Motor Outcome for DBS in Parkinson's Disease. *Ann Neurol* ana.25567-35.



Lead-DBS

Dembek et al., *Ann Neurol*. 2019  
<https://www.lead-dbs.org/>

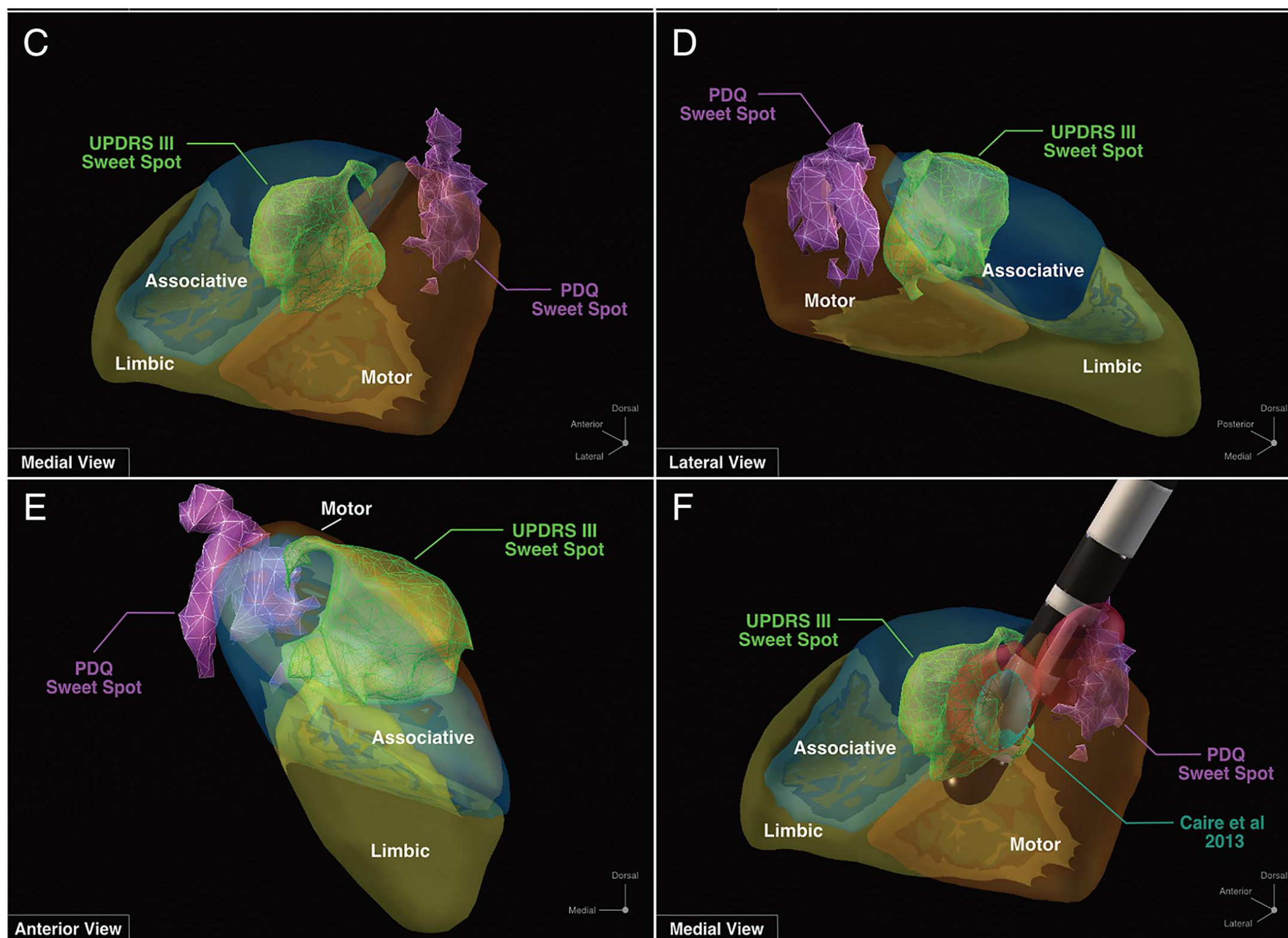
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## Searching best stimulating point by images



- ✓ PD with STN-DBS 69 cases from a subcohort of the EARLYSTIM study.
- The “sweet spots” differ between UPDRS-III and the PDQ-39
- In the left hemisphere, an area correlated with UPDRS-III was identified near the boundary between the motor and associative regions.
- The motor area contributed to improvements in the PDQ-39, but this was not statistically significant in the cross-validation analysis.
- The right hemisphere contributed more significantly to improvements in the PDQ-39.

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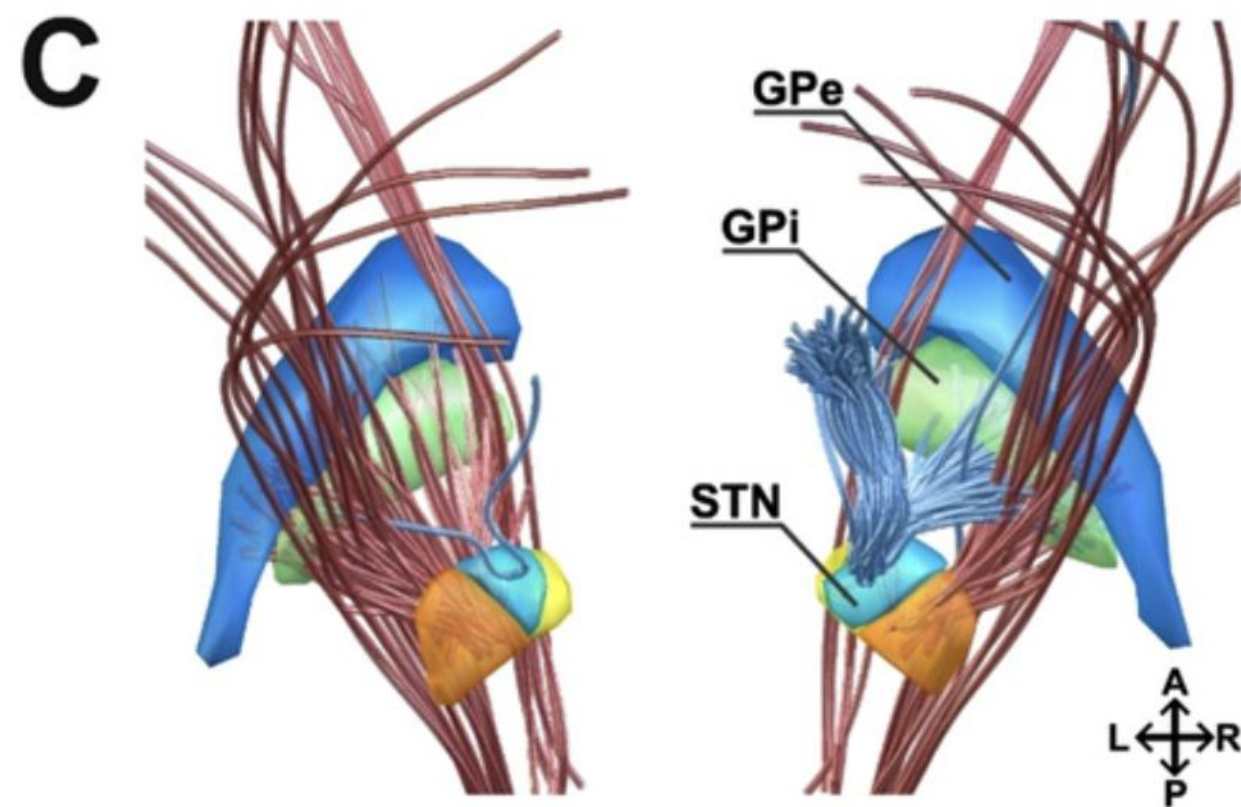
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## Avoiding adverse effect by images

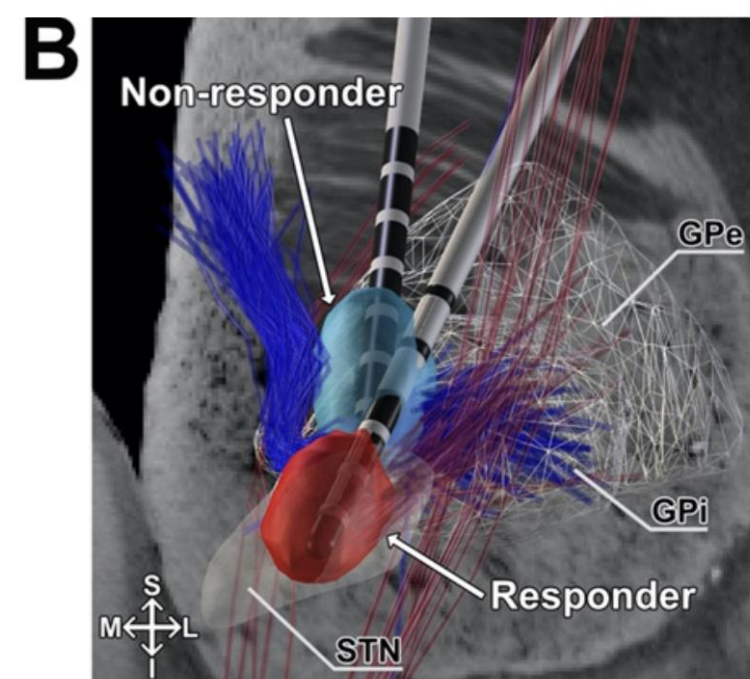
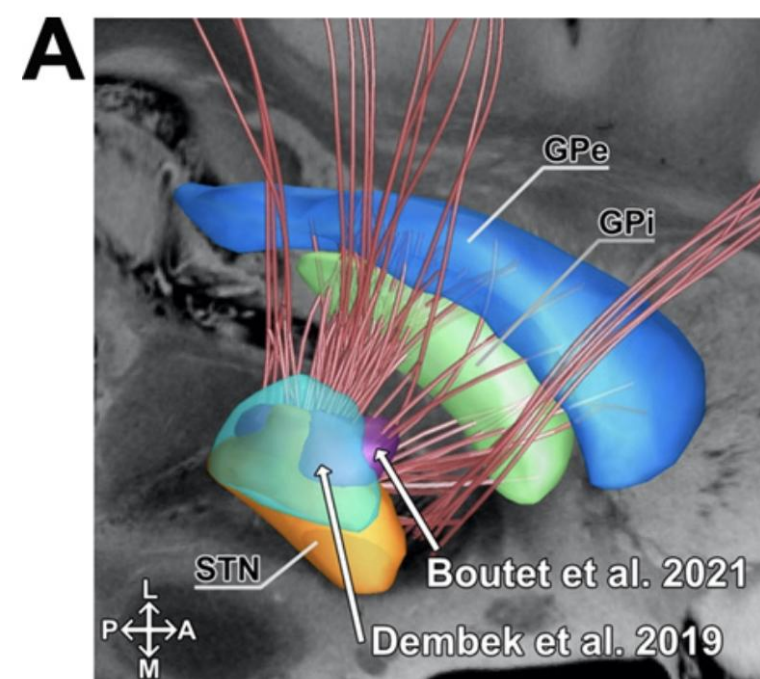
## FOG and Stimulation



- 47 patients with PD who had freezing of gait
- Identified electrode locations and the VTA using Lead-DBS
- Identified nerve fibers connected to the stimulation site using the BG-IC connectome
- Assessed freezing of gait during a dual-task using video analysis and questionnaires

✓ Stimulation of the hyperdirect pathway connecting to the motor cortex, premotor cortex, supplementary motor area, and dorsolateral prefrontal cortex (dlPFC) correlated with improved freezing of gait.

✓ Stimulation of the right lenticular fasciculus was associated with worsening of freezing of gait.



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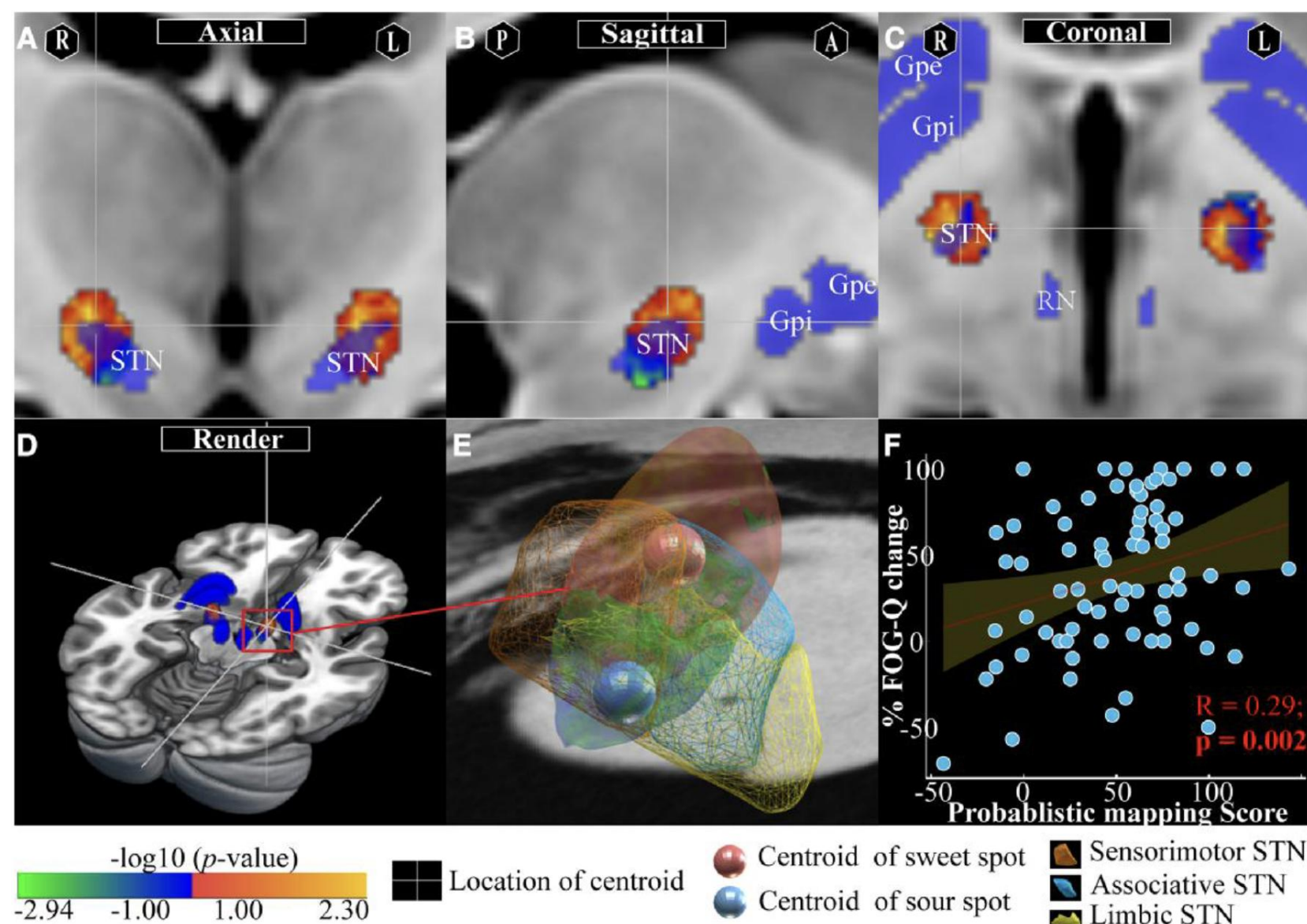
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## Avoiding adverse effect by images

## FOG and Stimulation



76 PD with FOG who underwent STN-DBS ( >90 Hz )

### Sweet spot:

#### Dorsolateral two-thirds of the STN

Significant correlation between stimulation site and FOG improvement was observed only in the right hemisphere.

It was suggested that the **right STN may play a dominant role in “inhibitory control” and “postural control”** in coordination with the supplementary motor area (SMA), prefrontal cortex, and walking centers.

### Sour spots:

Right hemisphere: Vento-central portion of the STN

Left hemisphere: Internal capsule surrounding the central portion of the STN

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## STN programming by images

- “**sweet spot**” is often estimated to be located near the boundary between the motor and associative areas, while the limbic system is frequently identified as an area must to be avoided.
- Possible lateral differences:  
Is there a sweet spot in the right STN for the PDQ-39 and for the “FOG” symptom?

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## Image Guided Programming

BRAINLAB ELEMENTS / BostonScientific GUIDE XT / StimView XT

**Boston Scientific**  
Advancing science for life™

**Guide XT™** allows  
YOU to correlate  
stimulation location to  
clinical outcomes and  
programming efficiency

NM-1100203-AA

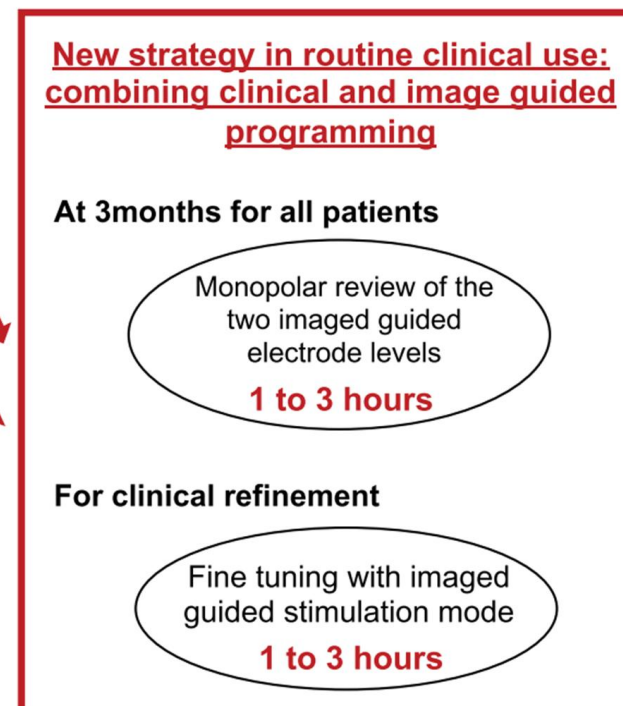
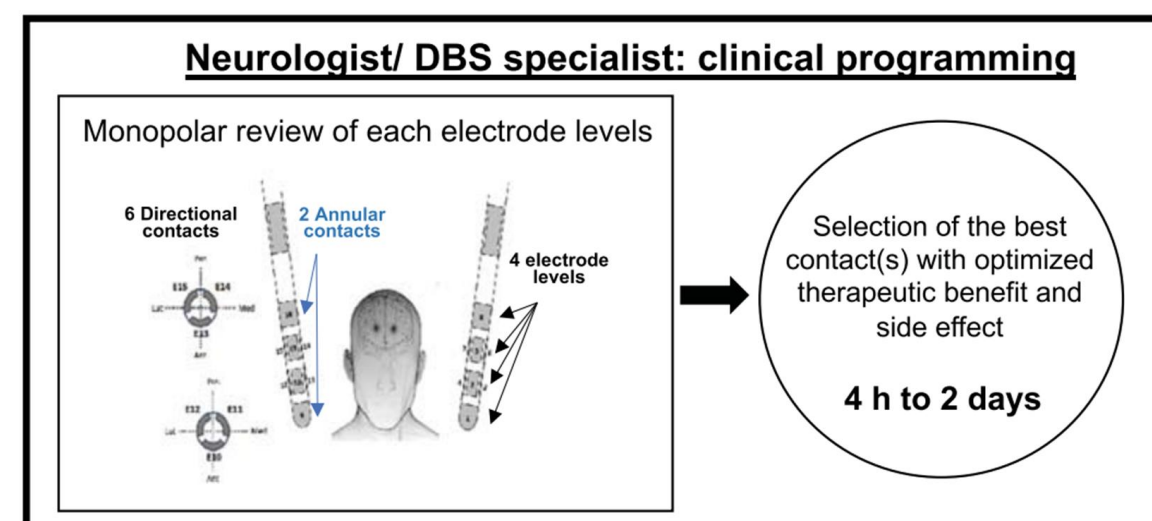
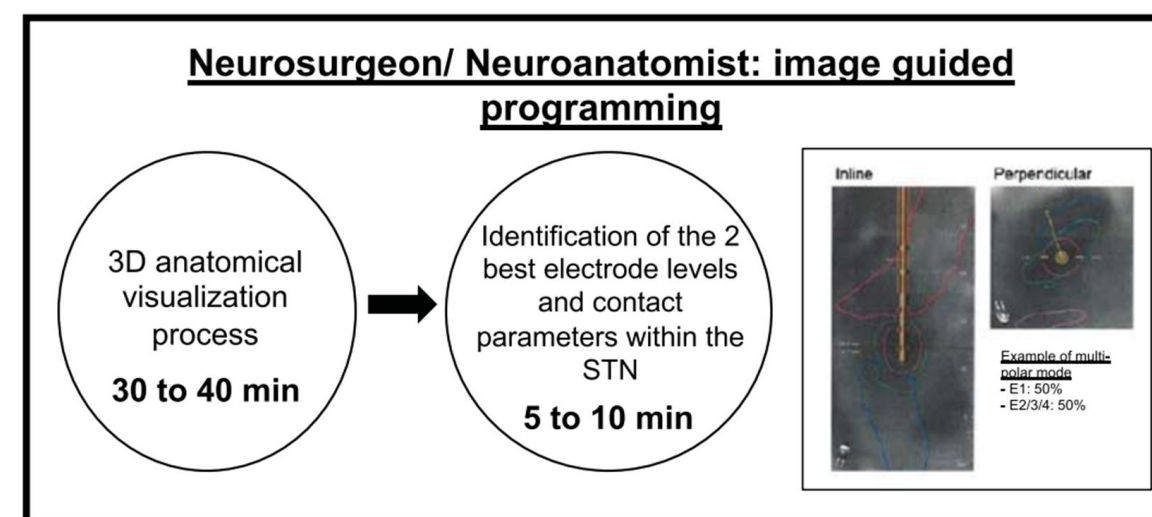
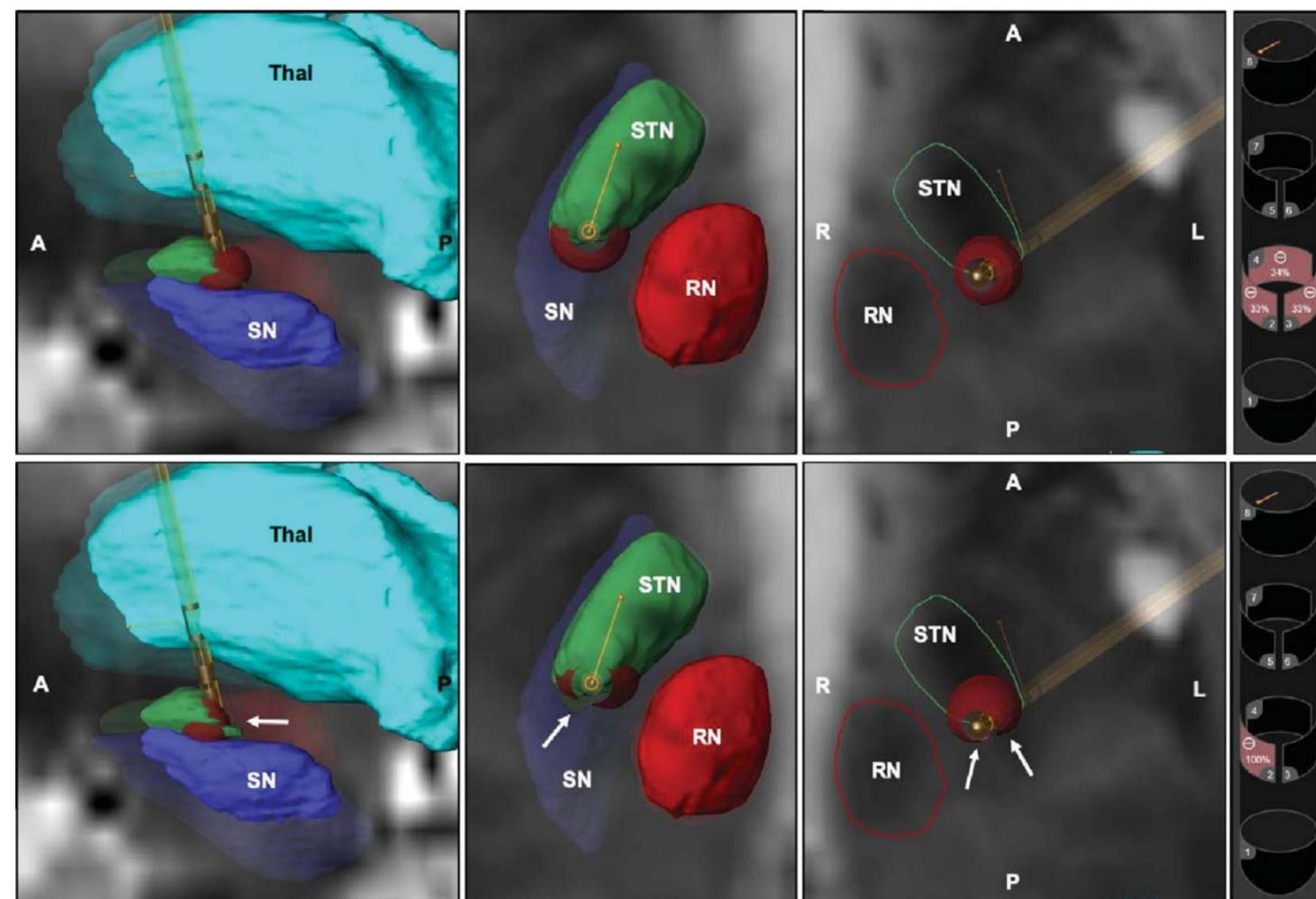
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## Can Image Guided Programming simplify and shorten the task?



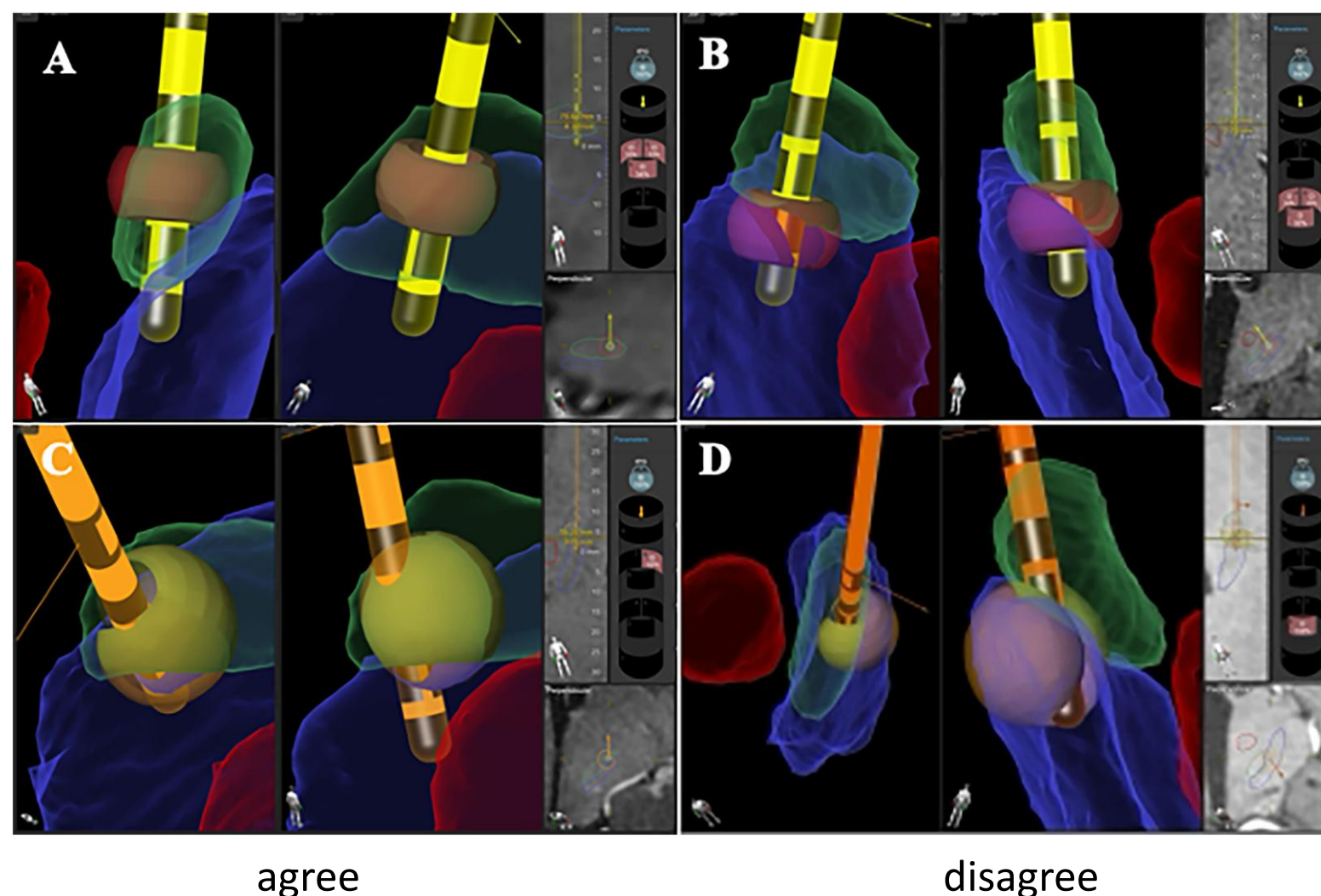
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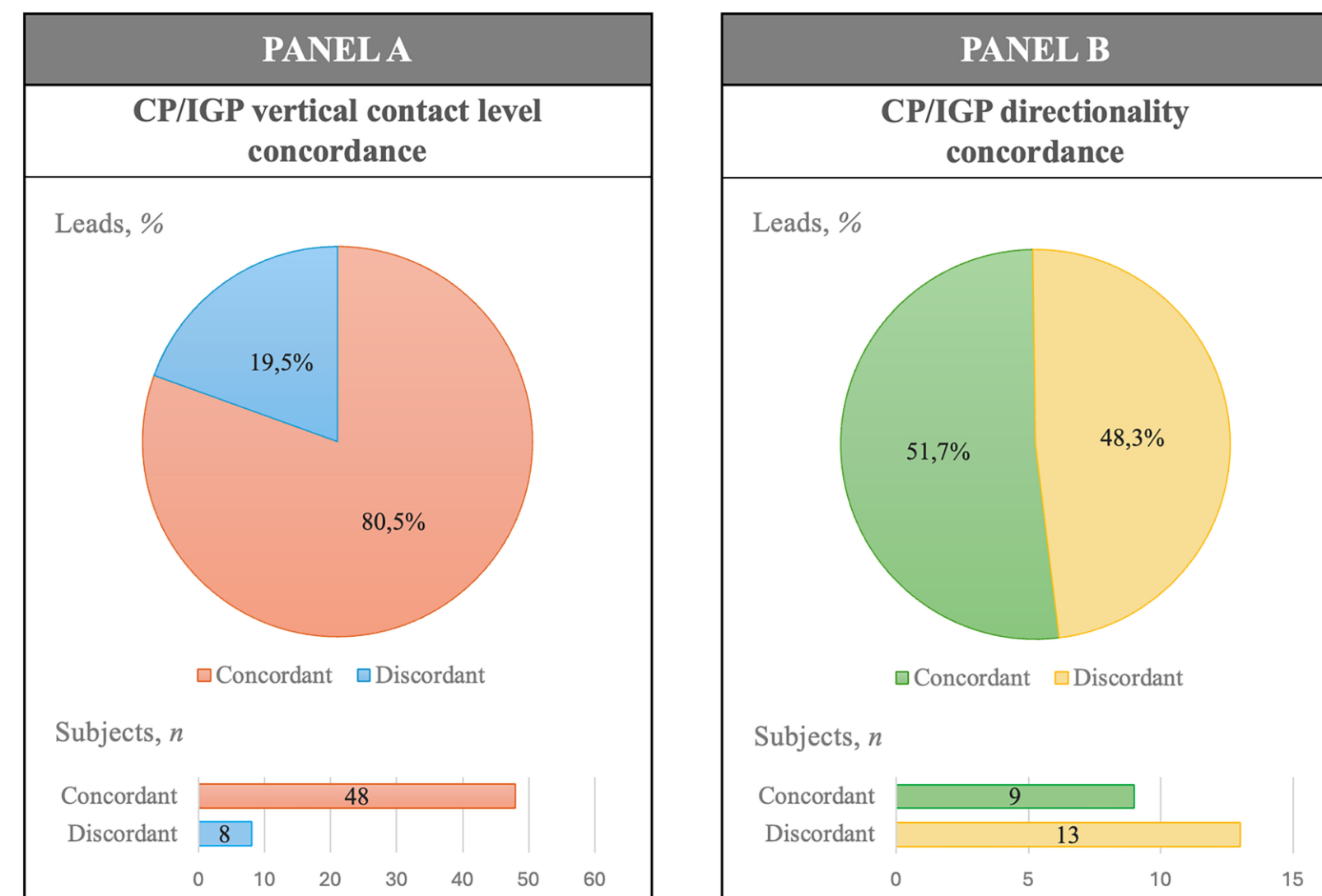


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## Image Guided Programming, longterm outcome



## One-year post-surgery



- ✓ No significant difference in motor outcomes was found between IGP/CP concordant and discordant patients for **contact level activation**
- ✓ Patients with concordant IGP/CP active directional stimulation (**c-Direction**) showed **superior motor outcomes at one-year follow-up than those discordant (d-Direction)**

➤ **It is important not to rely solely on IGP, but to make fine adjustments.**

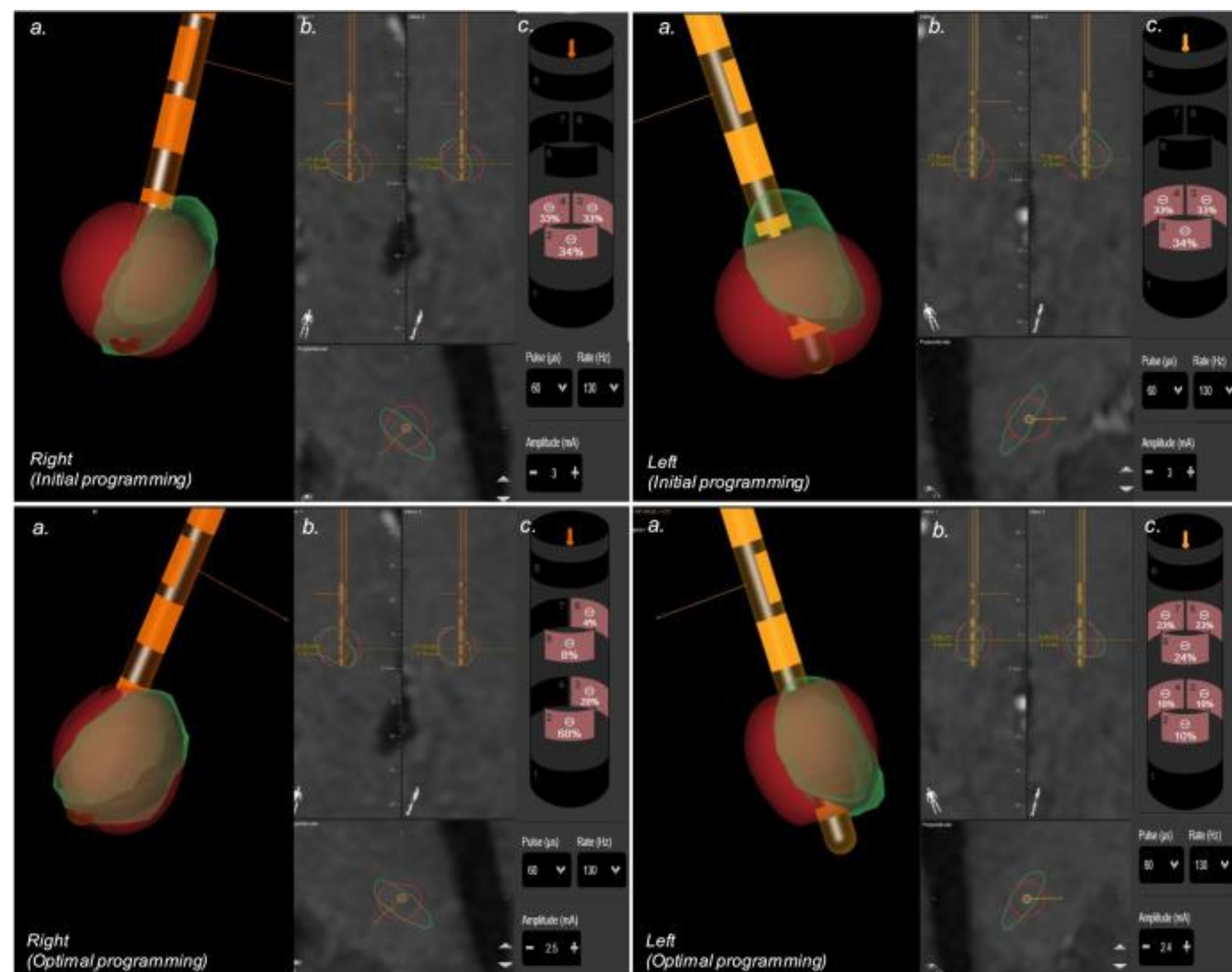
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## Image Guided Programming, re-programming



- 31 PD with STN-DBS and suboptimal responses refractory to clinical programming.
- Programming settings were adjusted by IGP (StimView XT software).
- After IGP, **83.9% experienced motor and QoL improvements**, with **25.8% feeling much better** and **38.7% feeling moderately better** according to the patient global impression scale.

- IGP optimizes STN-DBS therapy for PD patients who are experiencing suboptimal clinical outcomes.
- Using IGP as a **standard tool** in clinical practice, which could save programming time and improve patients' QoL.

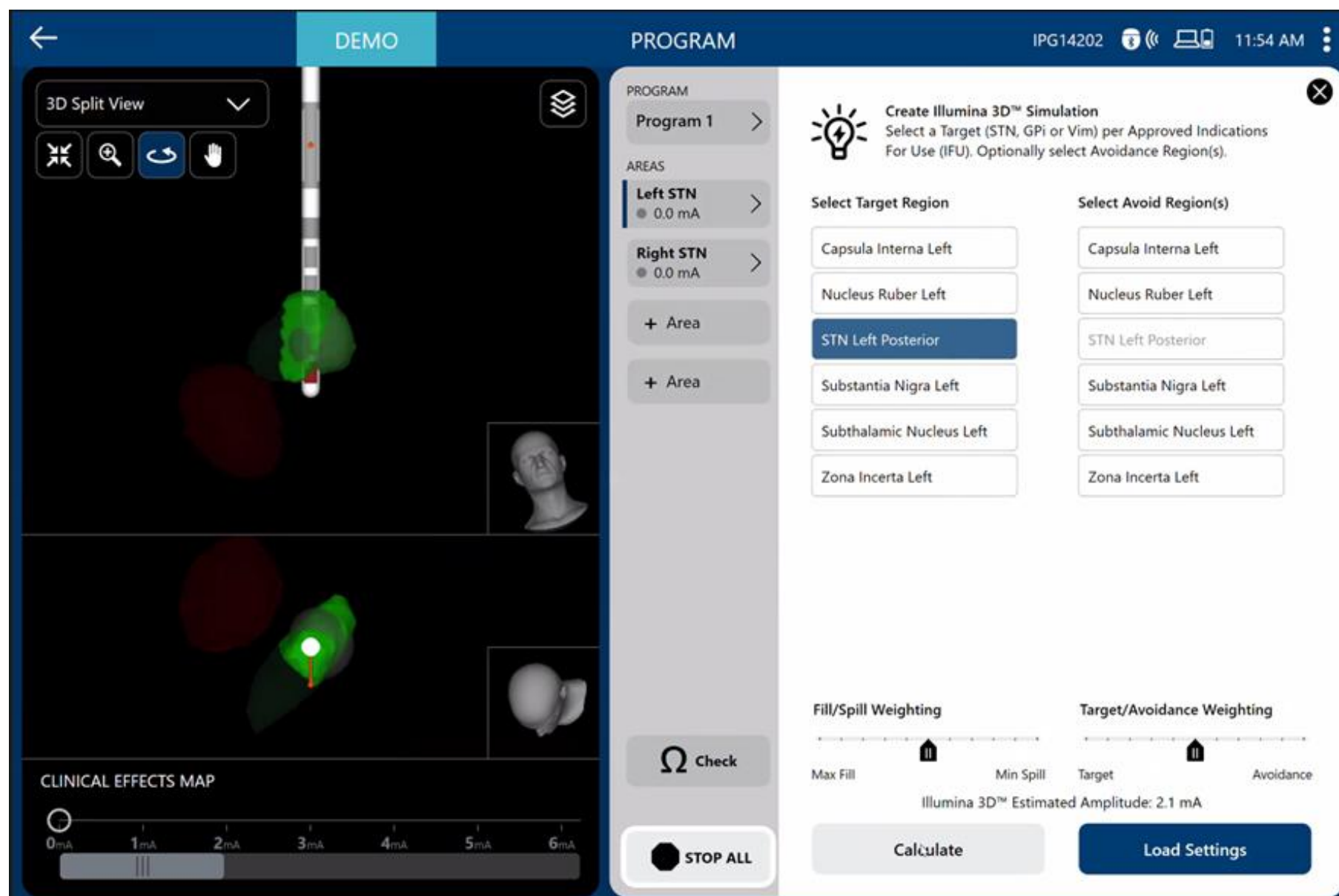
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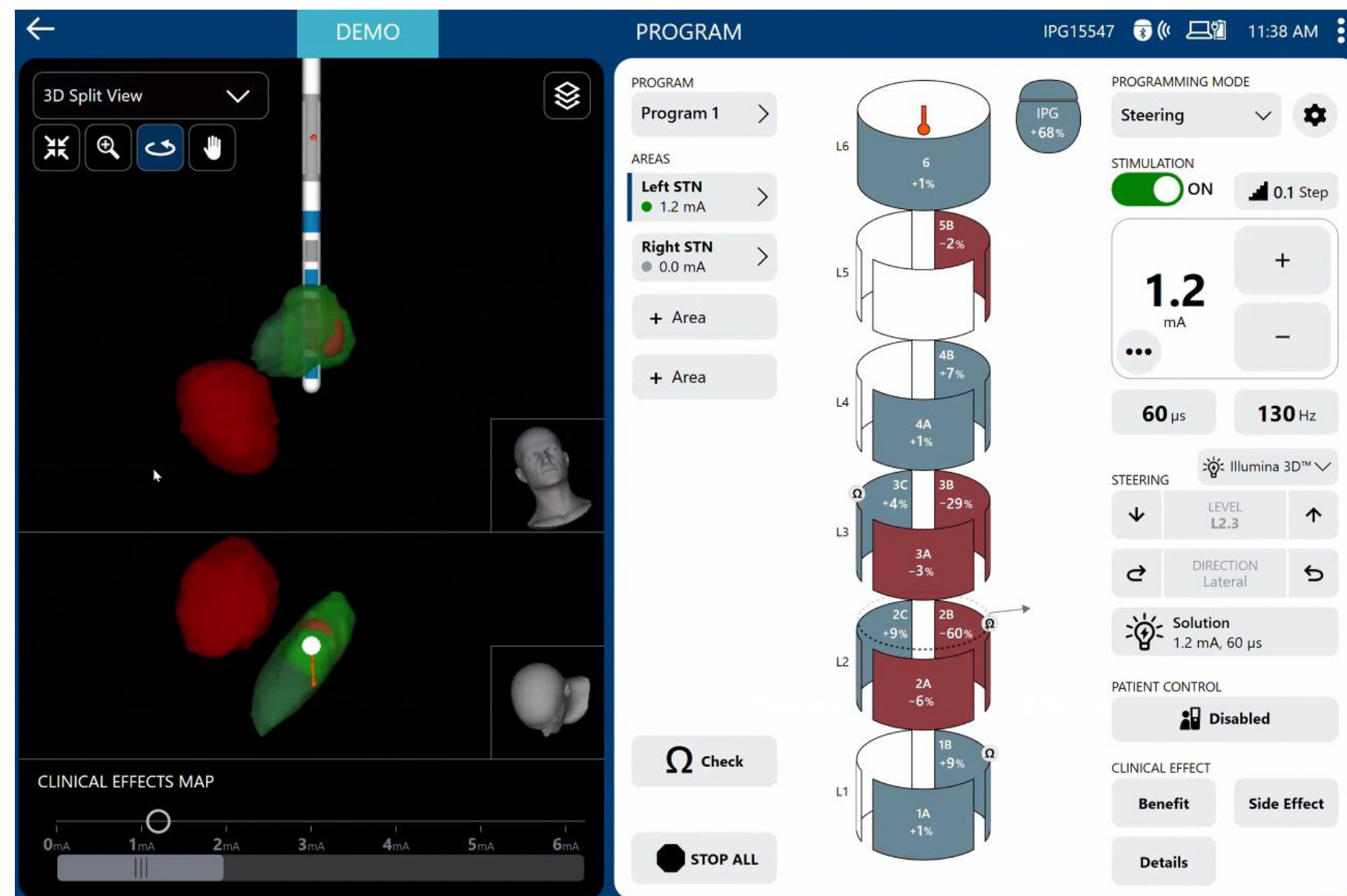
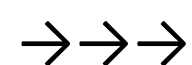


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## Automatic programming using image-guided software : BostonScientific Illumina 3D



Select target regions and avoid regions



Automated programs generated by the software

Adapted from the Sales materials of BostonScientific

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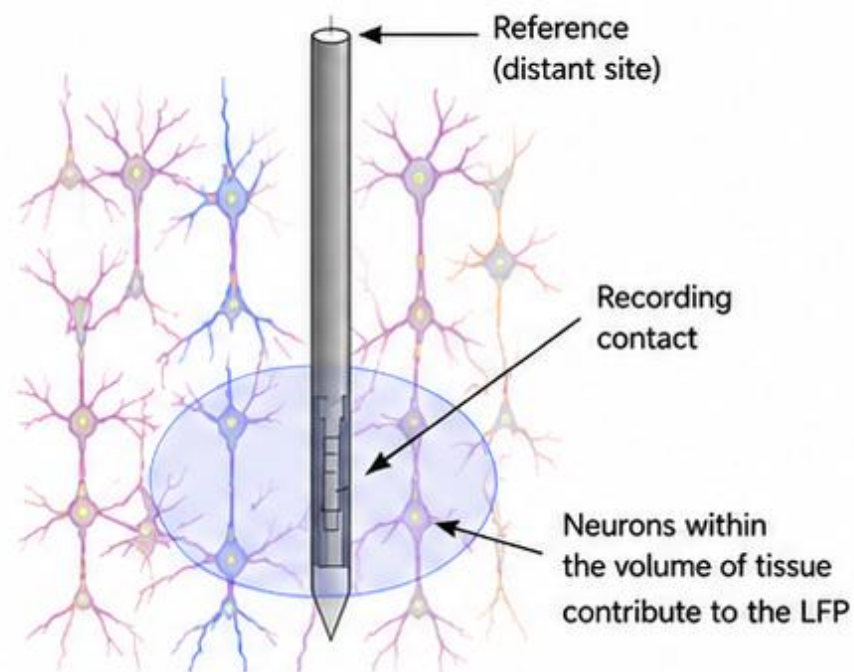
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## Local Field Potential(LFP) : A measure of the summed electrical activity of neuronal populations

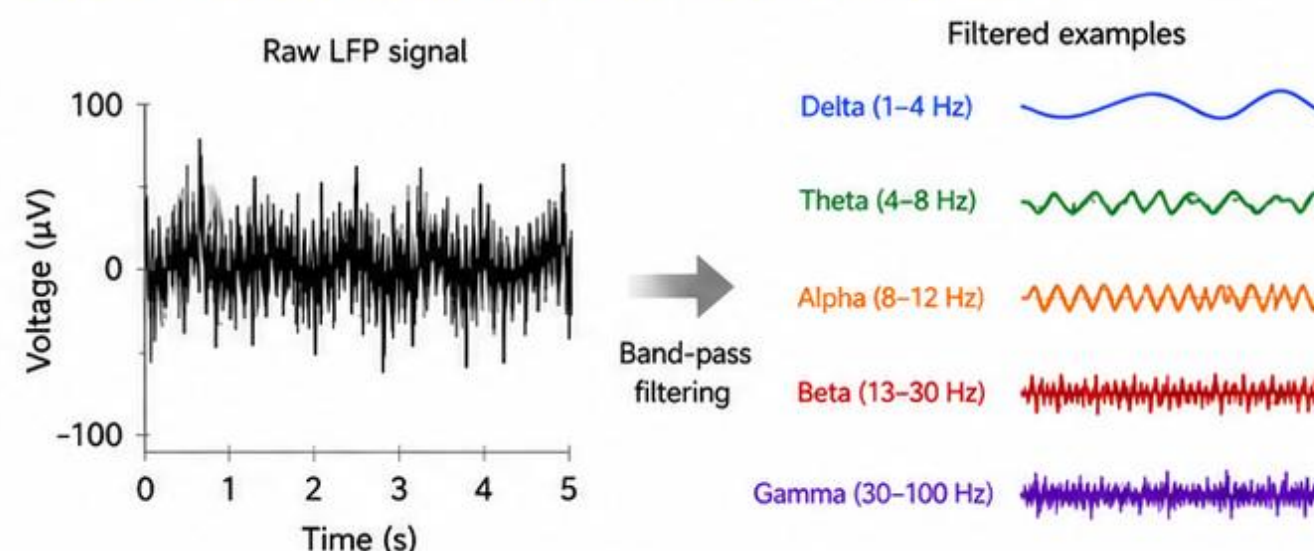
### Beta Oscillations in Parkinson's Disease Reflect Motor State (ON vs OFF)

#### 1. What is LFP?

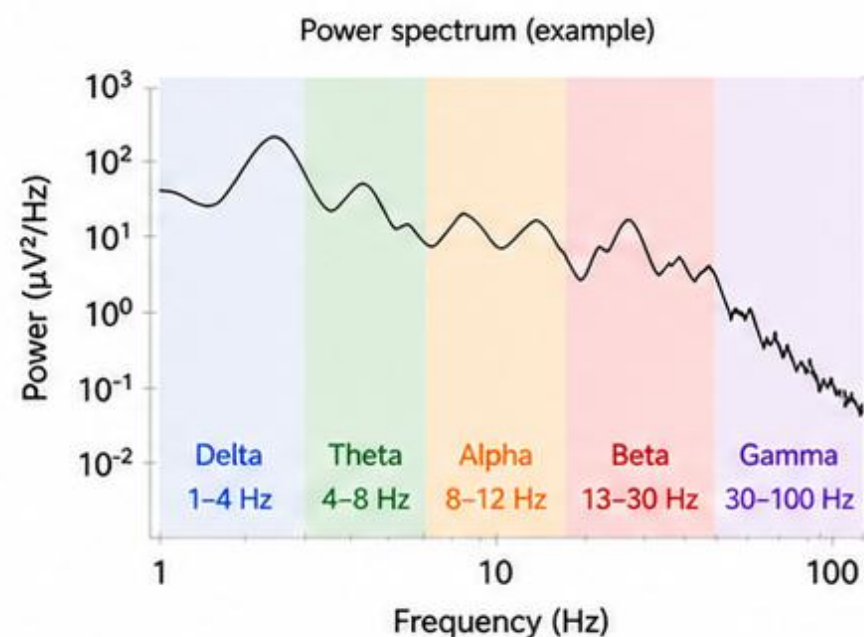
LFP is the extracellular voltage fluctuation generated by the summed synaptic and membrane activities of a large number of neighboring neurons.



#### 2. LFP contains oscillations across frequency bands



#### 3. Power spectrum of the LFP



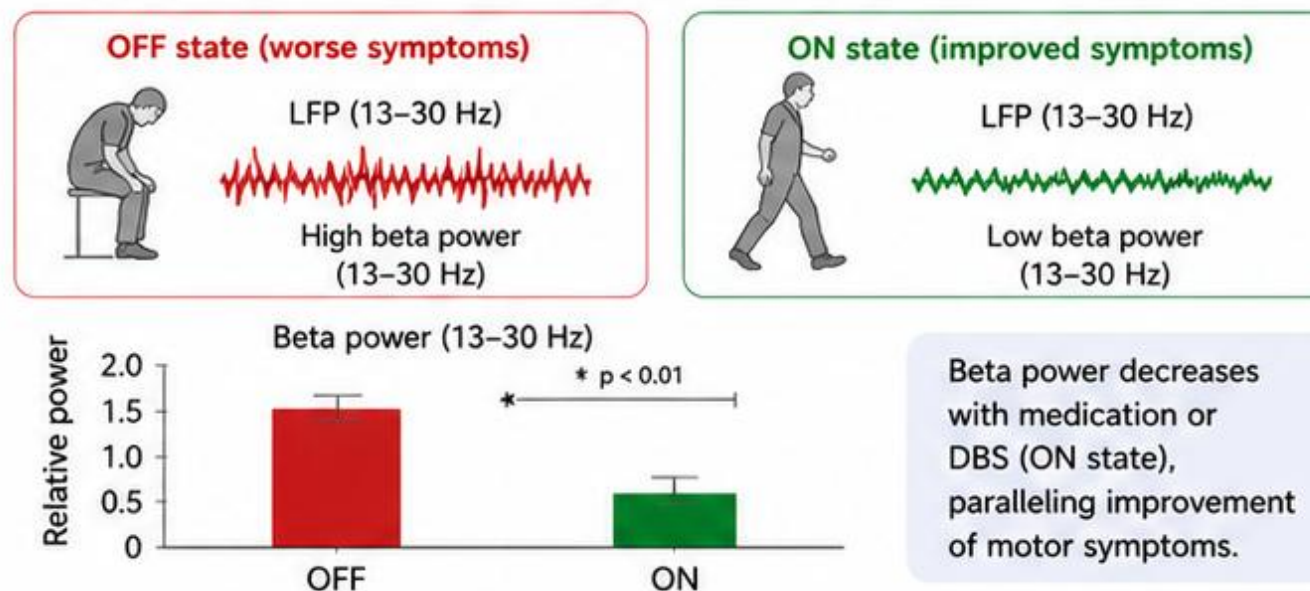
The power of specific frequency bands in the LFP is associated with behavioral and clinical states.

Examples in Parkinson's disease (STN LFP):

- Beta power  $\uparrow$  in OFF state (more symptoms)
- Beta power  $\downarrow$  in ON state (symptom improvement)

#### 4. Beta-band activity in Parkinson's disease changes with motor state

In Parkinson's disease, beta (13-30 Hz) power in motor-related regions (e.g., STN, motor cortex) is higher in the OFF state and suppressed in the ON state.



Figures by K.Kimura edited with GenAI

- Brown et al. Brain. 2007
- Kühn et al. Lancet Neurology. 2008
- Little S, Annals of Neurology. 2013
- de Hemptinne et al., Neuron. 2015
- Kühn et al., Clinical Neurophysiology. 2006
- Brown et al. 2005, Hammond et al. 2007
- Yin et al. Neurobiol Dis. 2021

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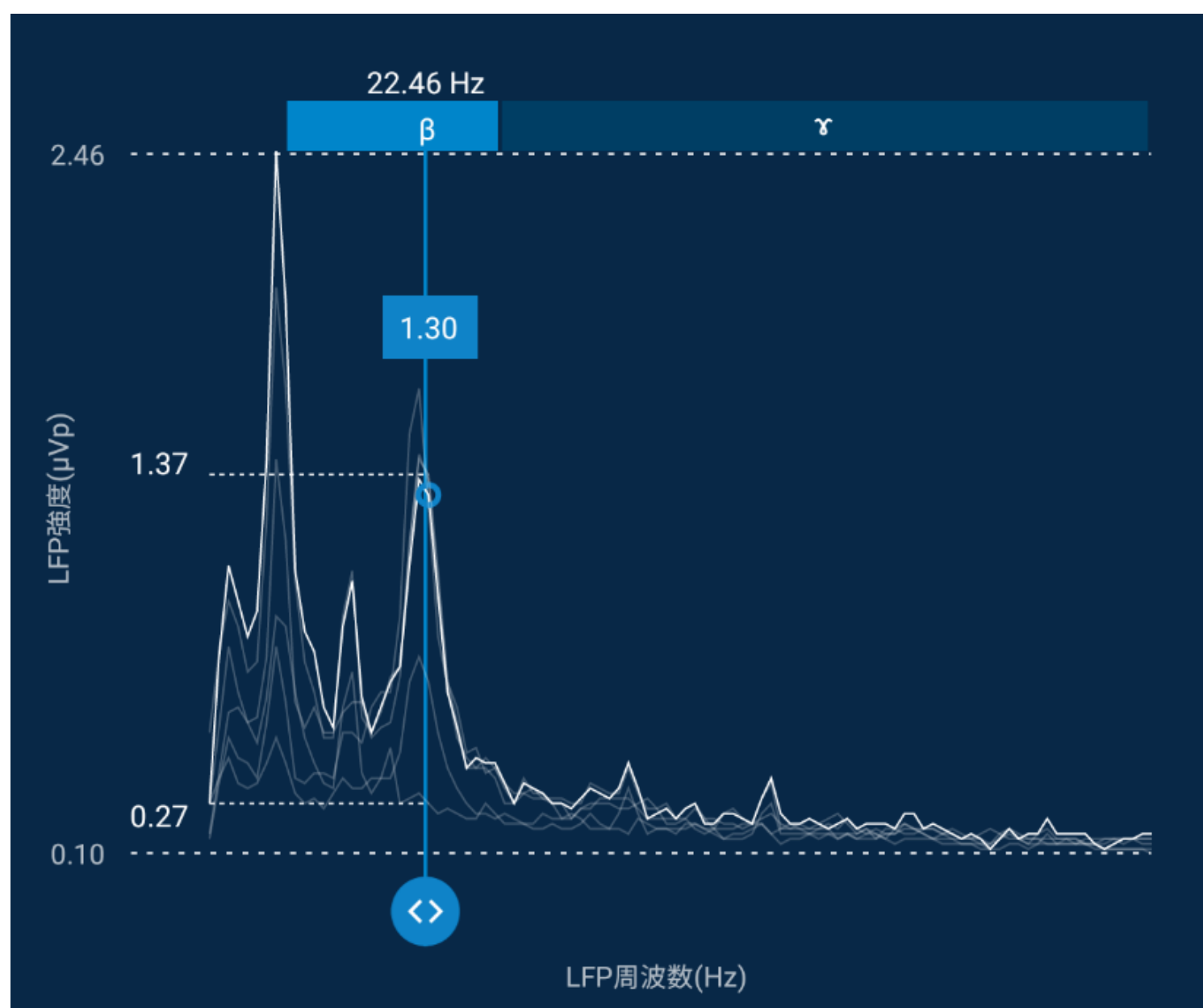
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LFP surveyed from lead at “Med-Off and Stim-off”

Medtronic **Brainsense** Survey



## • Low beta (13-20Hz)

- More dominant within the STN<sup>1)</sup>
- regarded as a pathological oscillation<sup>1)</sup>
- sensitive to meds<sup>2,3)</sup>
- higher in untreated<sup>4,5)</sup>
- The power correlates with the disease severity<sup>2)</sup>
- correlated with UPDRS-III scores<sup>6,7,8)</sup>

## • High beta(21-35Hz)

- more related to long-distance (interregional) coupling<sup>9)</sup>
- High β within the STN correlates with cortical motor association areas<sup>9)</sup>
- the electrophysiological manifestation of the hyperdirect pathway<sup>10-12)</sup>

<sup>1)</sup>Tsiokos et al., 2017, <sup>2)</sup> Neumann et al., 2016, <sup>3)</sup> Priori et al., 2004, <sup>4)</sup>Lopez-Azcarate et al., 2010, <sup>5)</sup> Oswal et al., 2016, <sup>6)</sup> Florin et al., 2013, <sup>7)</sup> Steiner et al., 2017,

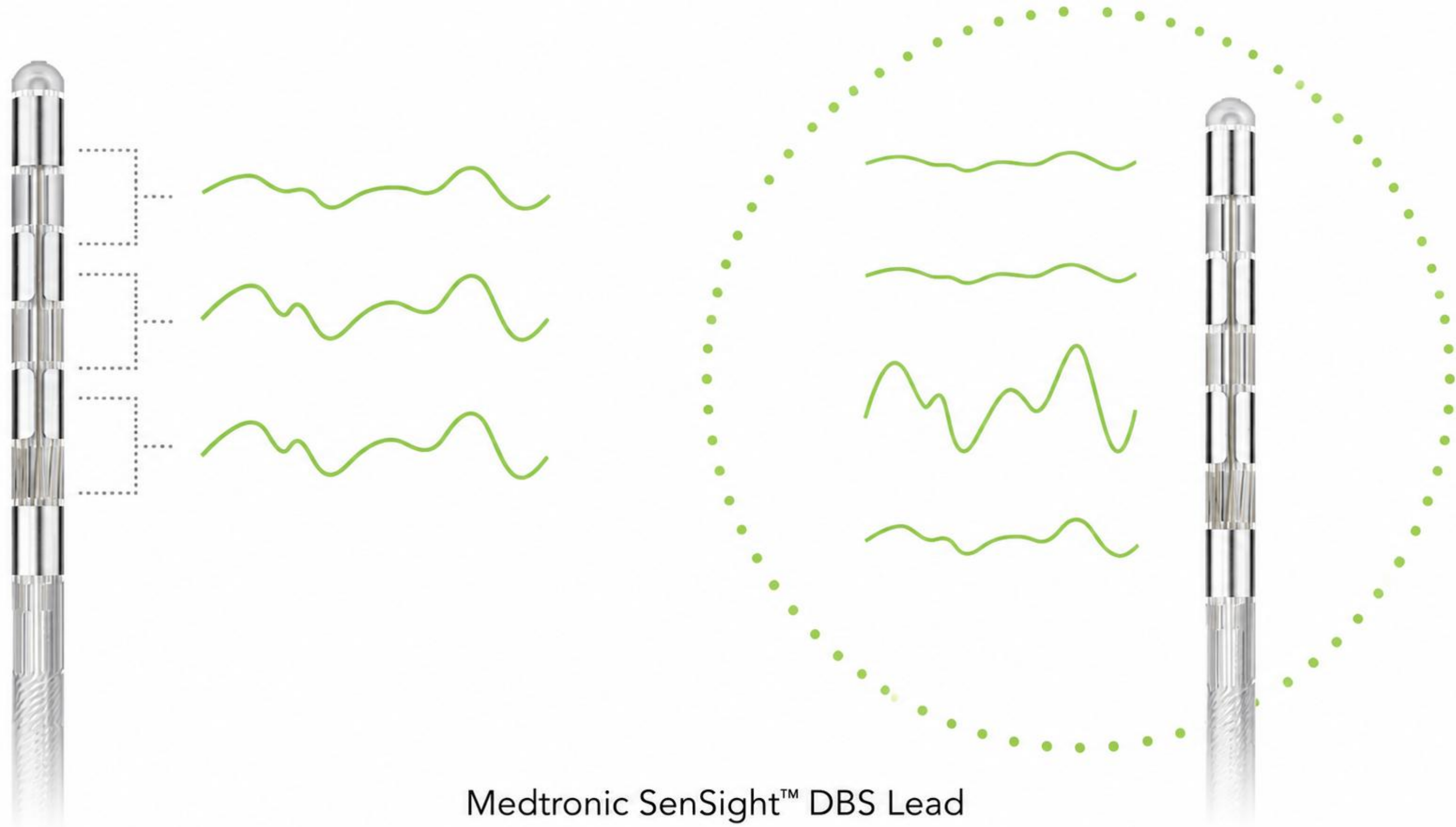
<sup>8)</sup> Storzer et al. 2017, <sup>9)</sup> Ozturk et al. 2019, <sup>10)</sup> Florin et al. 2013, <sup>11)</sup> Blumenfeld et al. 2017, <sup>12)</sup> Ozturk et al. 2019

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← BRAINSENSE SURVEYS

Stimulation  On



LEAD LOCATION

Right STN

Electrode Identifier

Electrode Survey




Levels Segments

Results for the last Electrode Identification are shown. Results may differ between both levels and segments.

 REFRESH  
ELECTRODE IDENTIFIER

LFP Signal

The dots indicate the relative LFP magnitude strength. Electrode(s) with the highest LFP magnitude(s) may provide a starting point for monopolar review.

-  Most LFP Magnitude
-  Medium LFP Magnitude
-  Least LFP Magnitude



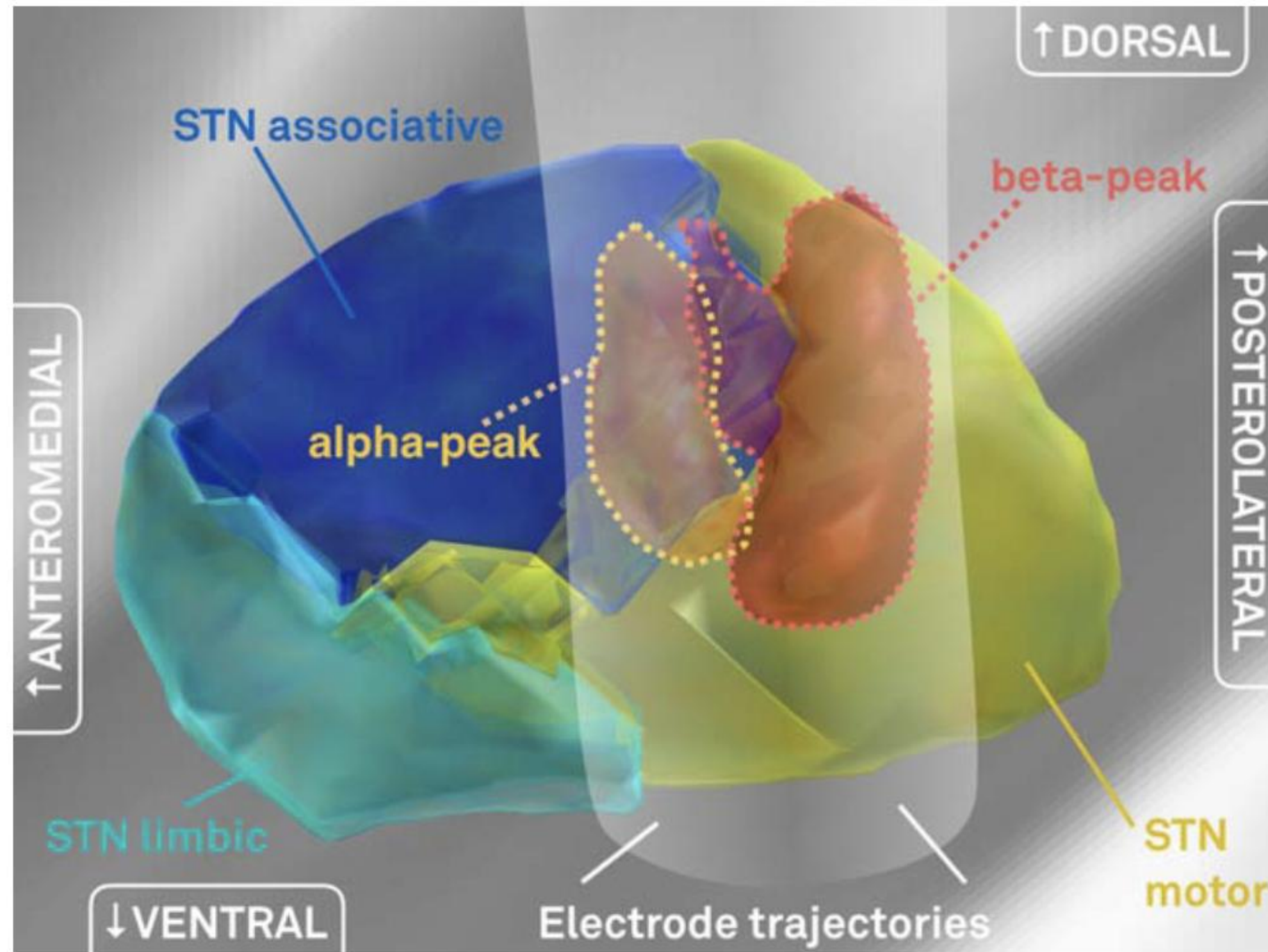
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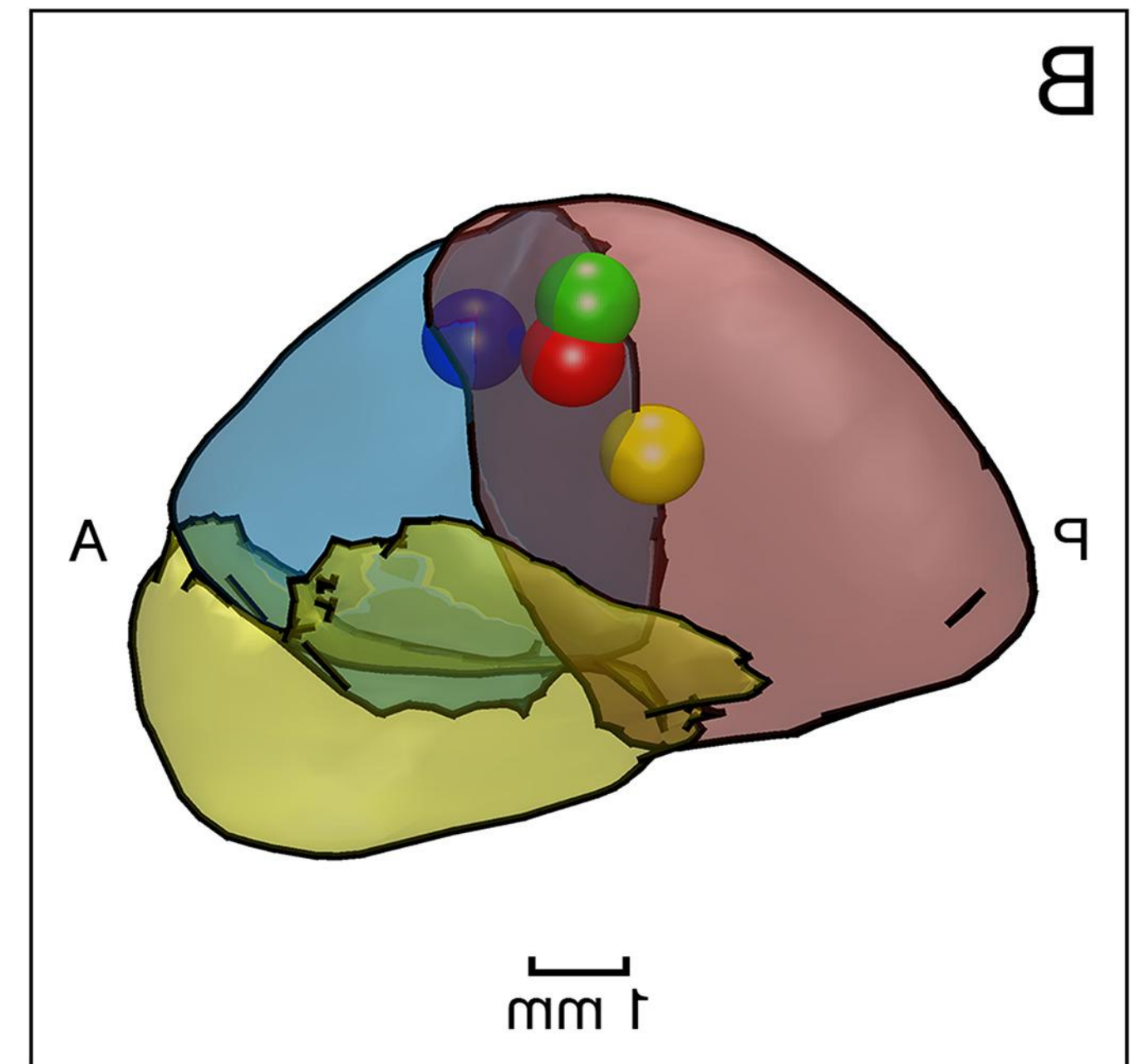
## beta oscillation



Horn et al., Hum Brain Mapp. 2017, Neuroimage, 2018 170, 271-282

## Sweet Spot

determined by Monopolar Review



Dembek et al., Ann. Neurol. 2019

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Programming / Clinical evaluation - Possibilities for Avoiding overstimulation

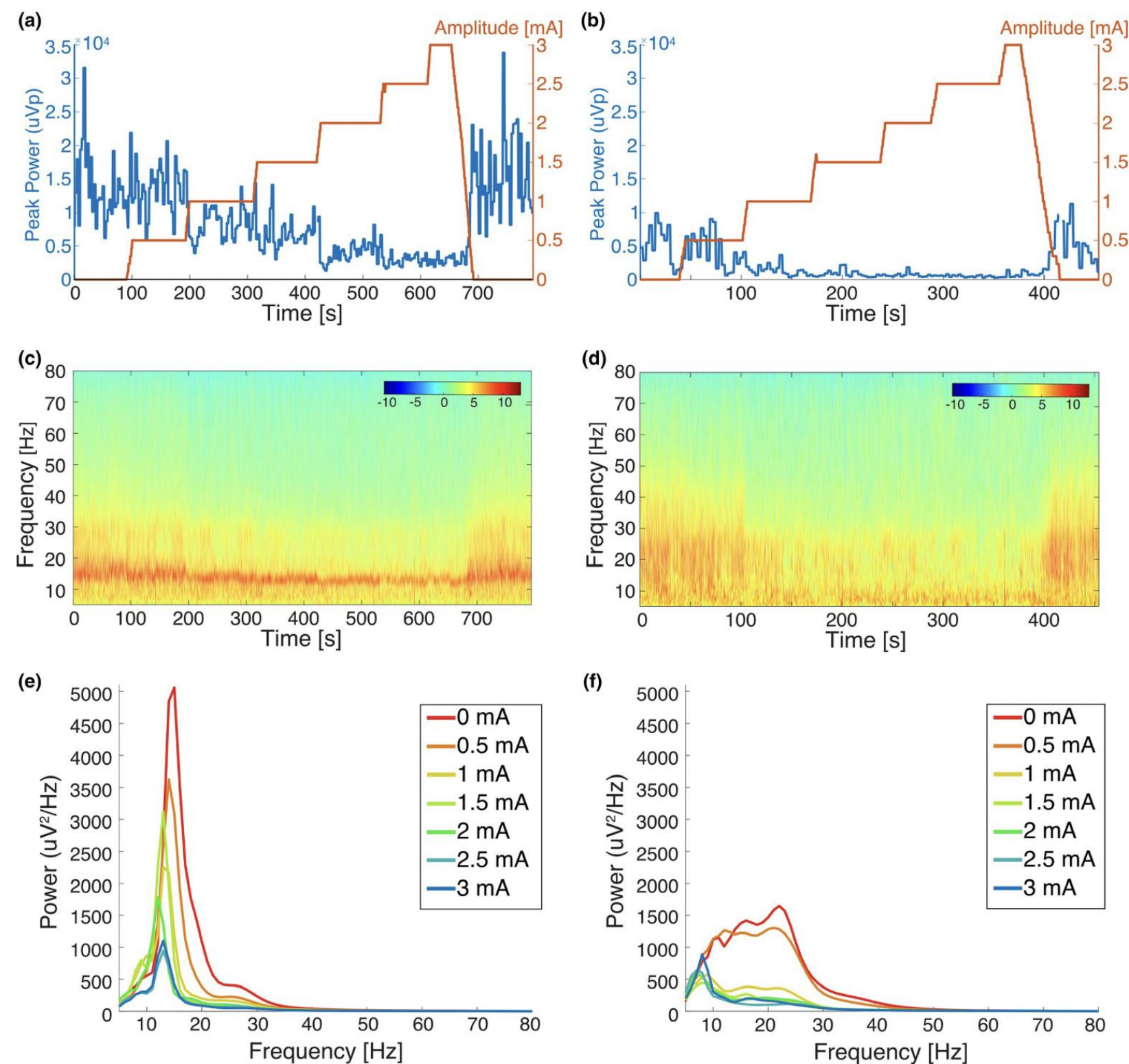


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## Stimulating Power Optimisation



Own data



LK Feldmann et al. Eur J Neurol. 2021. PMID: 33675144

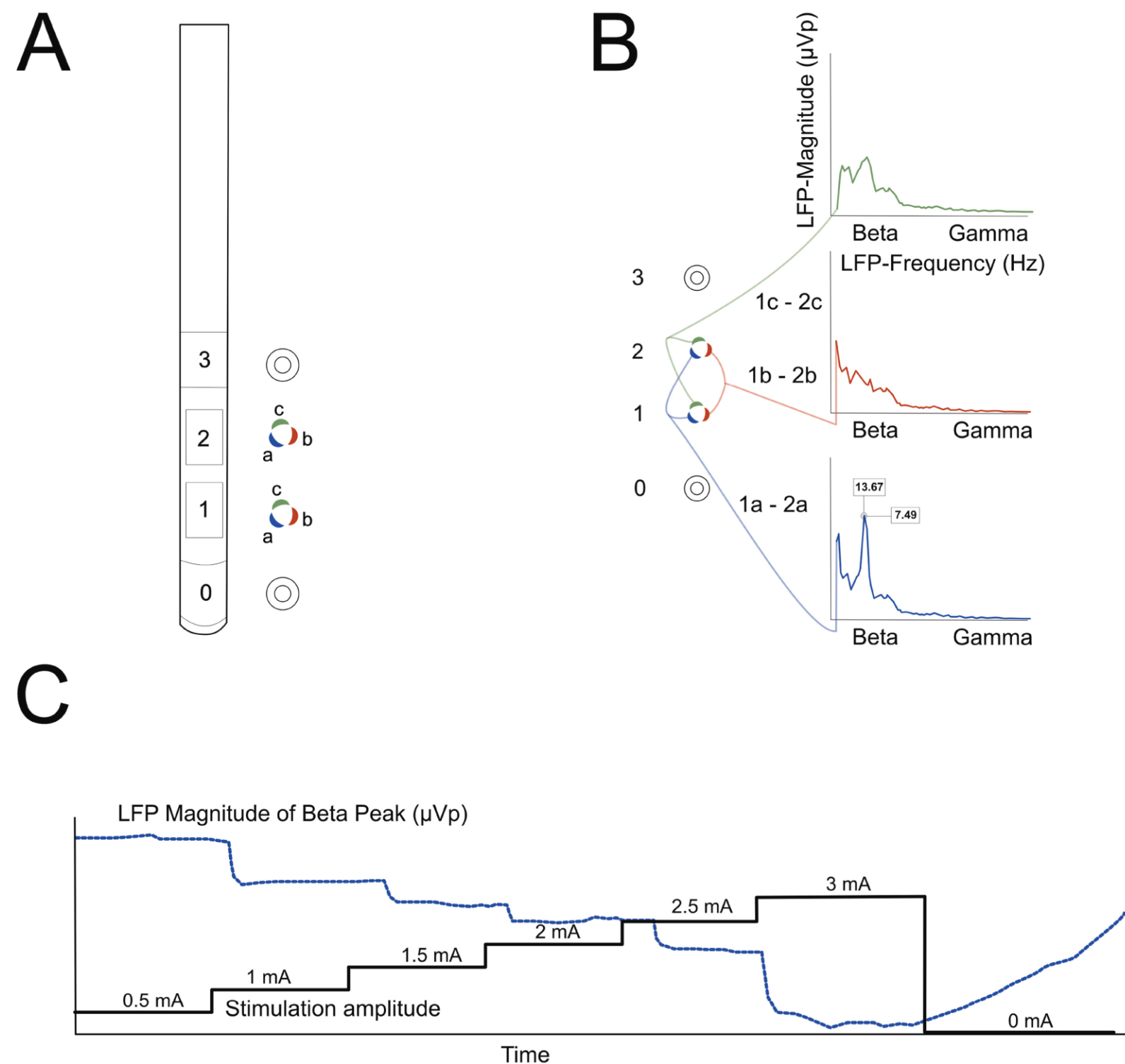
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## LFP signals can be a Potential biomarker for programming?



To compare **three programming strategies**:

**LFP-guided** (beta power)

Clinically guided (standard **monopolar review**)

**Image-guided**

Evaluate:

Clinical efficacy, Programming time, Stimulation parameters

8 PD with STN-DBS, 3 months after surgery

## Results

**Programming time: Significantly shorter** with

LFP-guided and Image-guided

vs clinical programming ( **$p < 0.001$** )

No major differences in:

Energy delivered, Stimulation parameters, Clinical Outcomes

## Conclusion

**LFP-guided programming is feasible and efficient**

**Provides similar symptom control with less programming time**

# School for Device-Aided Therapies in Parkinson's Disease

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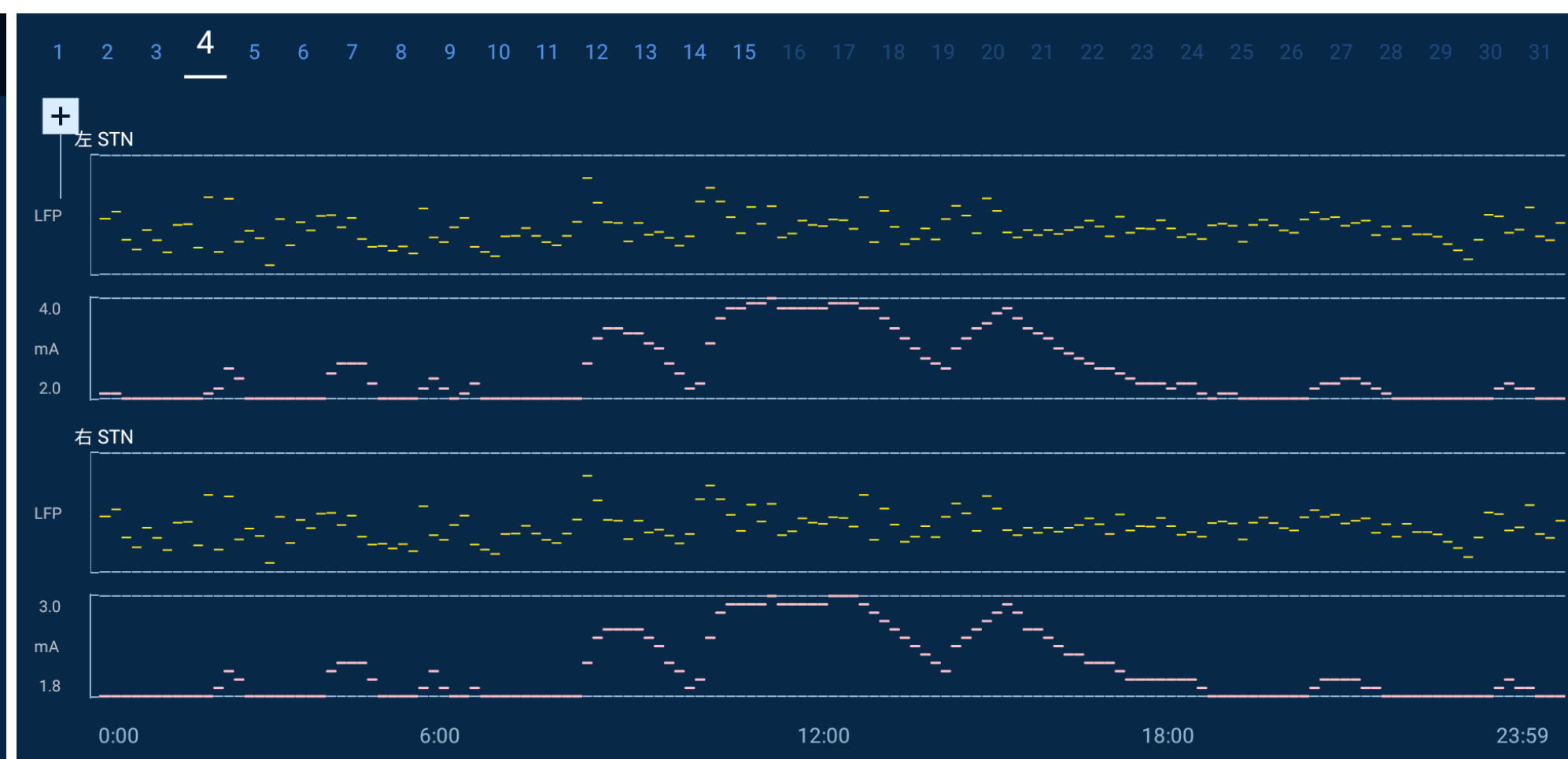
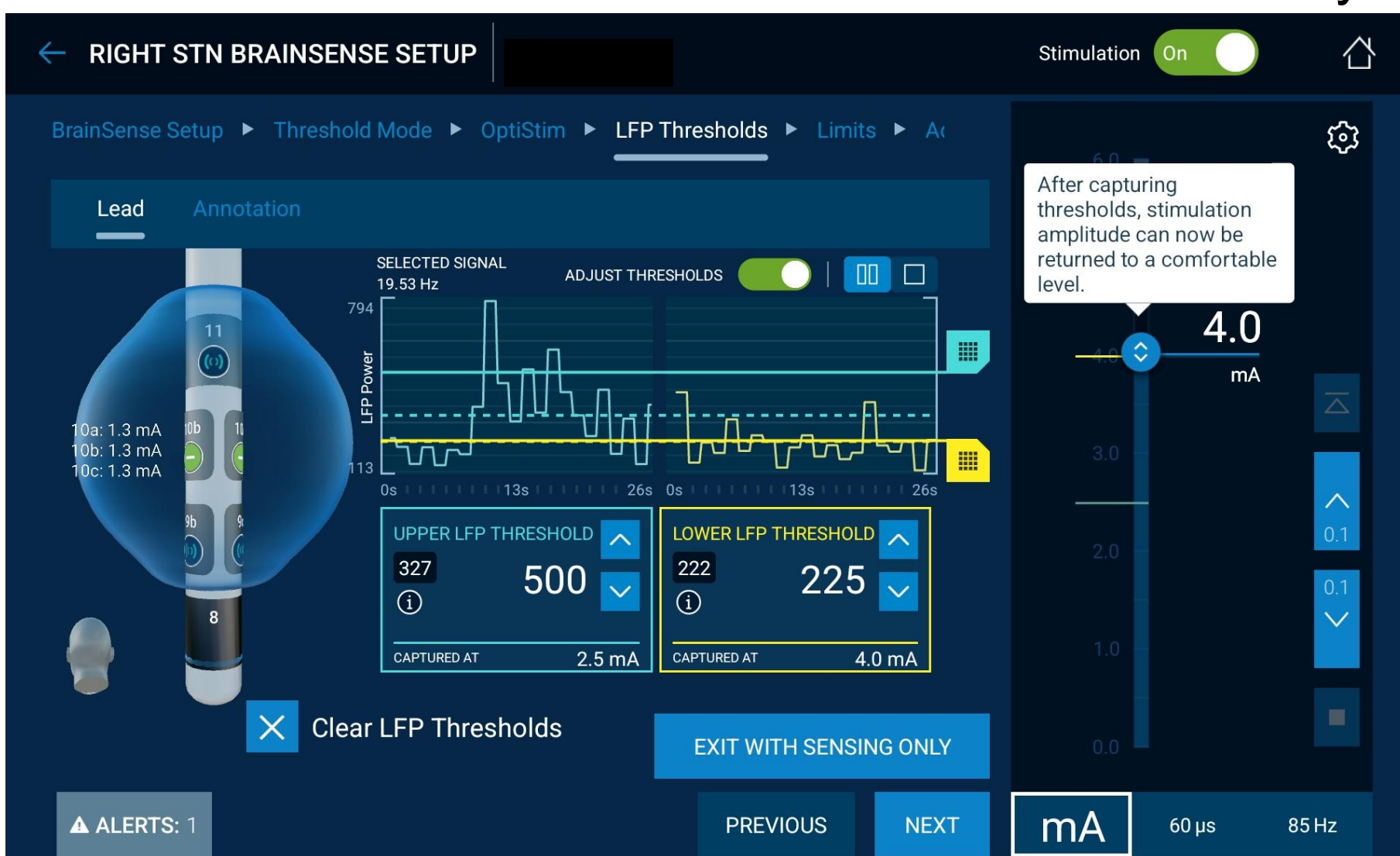


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## When to stimulate?

## Adaptive DBS: Personalized programming

60 y.o. PD Female



- The DBS stimulator analyzes LFP signals and adjusts stimulation settings within a preset range.
- Compared to conventional DBS, adaptive DBS allows for adjustments to stimulation based on factors such as medication effects (on-off phenomena) and the onset of dyskinesia.

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Updates on DBS Programming: Image-guided programming and LFP-based programming

## Conclusion

- Initial programming after DBS implantation has traditionally relied on **monopolar review**.
- Conventional programming is effective but can be:
  - Time-consuming
  - Operator-dependent
- New technologies are now clinically available such as:
  - **Image-guided programming**
  - **LFP sensing-based programming**
- These approaches may:
  - Improve programming efficiency
  - Support objective contact selection
  - Reduce patient and clinician burden
  - **Technology is not perfect; clinicians must always confirm the outcomes.**



✓ More options for individualizing DBS therapy will be available.

Questions & comments are welcome : [katsuo@yokohama-cu.ac.jp](mailto:katsuo@yokohama-cu.ac.jp)