

# Update on DBS Device and Surgery: Neurologists' and Neurosurgeons' Perspectives

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# Two Different Prospective

## Neurologists' Prospective

### Indication

- Age
- Genetic
- Phenotype
- Target

### Programming

- Image-guided programming
- AI based programming
- Local field potential

## Neurosurgeons' Prospective

### Surgery

- Robot surgery
- Asleep or awake surgery
- Lead depth

Troubleshooting

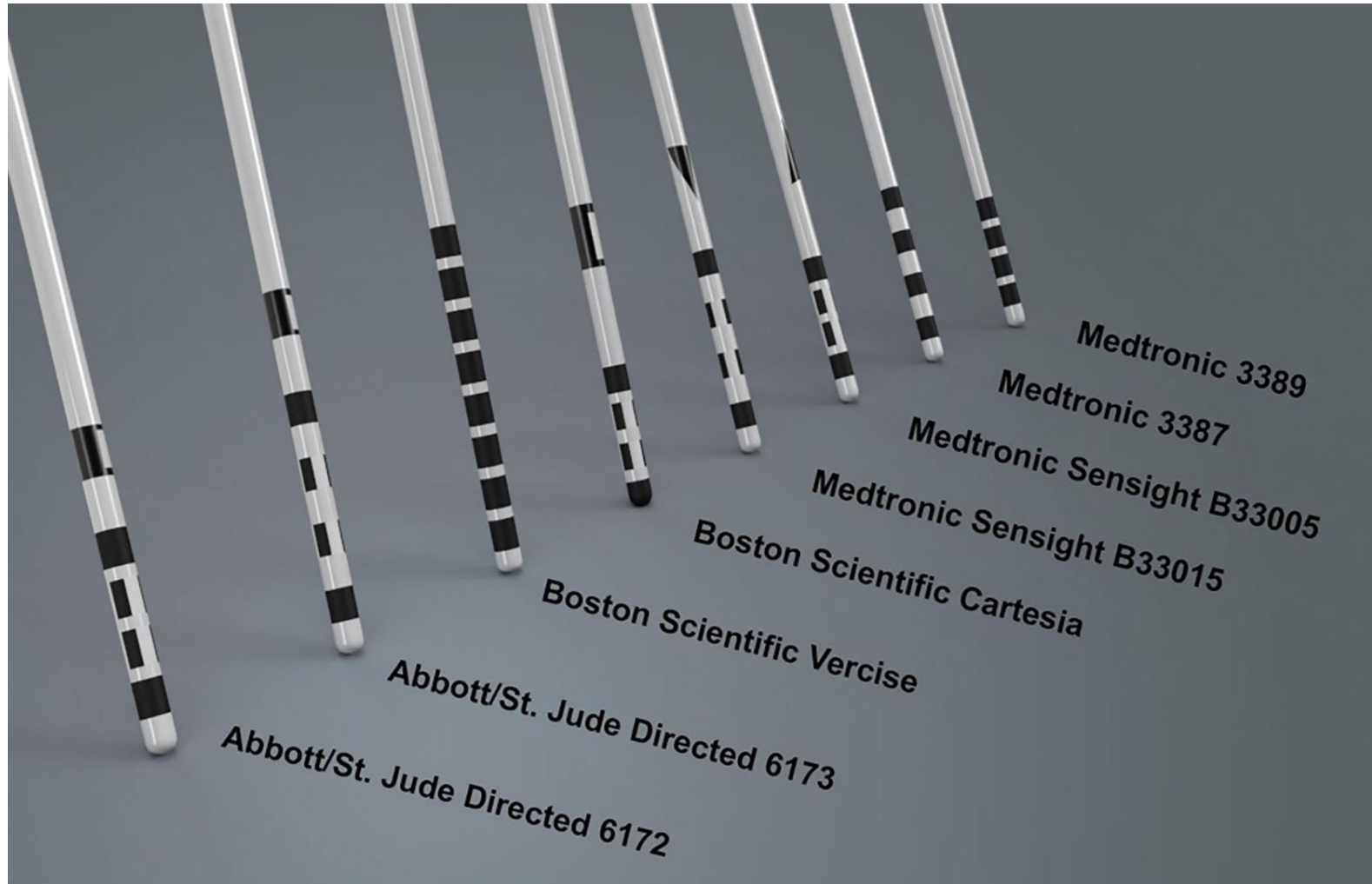
# Contents

1. What are the updates in DBS field?
2. Updates in Neurosurgeons' prospective
3. Updates in Neurologists' prospective

# Updates in DBS

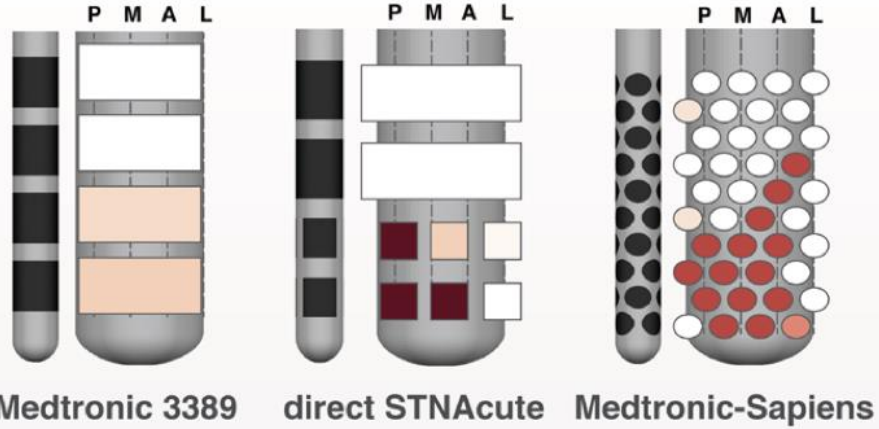
- Electrodes
- Implatable Pulse Generator (IPG) or battery
- Programmers
- Surgery

# Updates in Electrodes

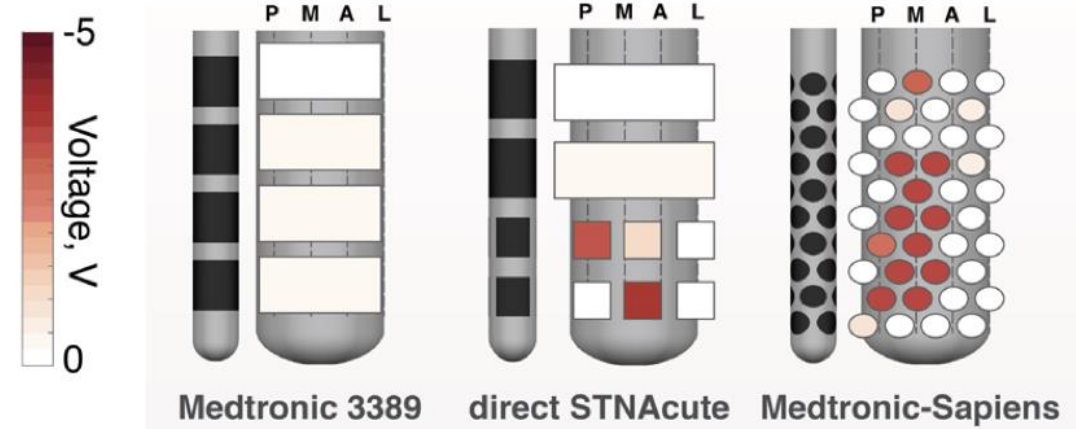


Frey J et al. 2022

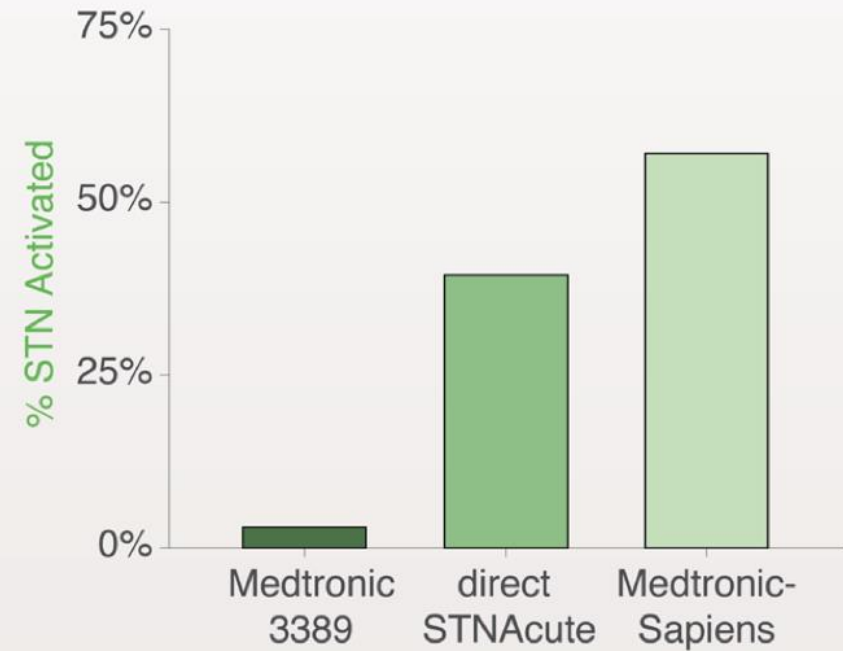
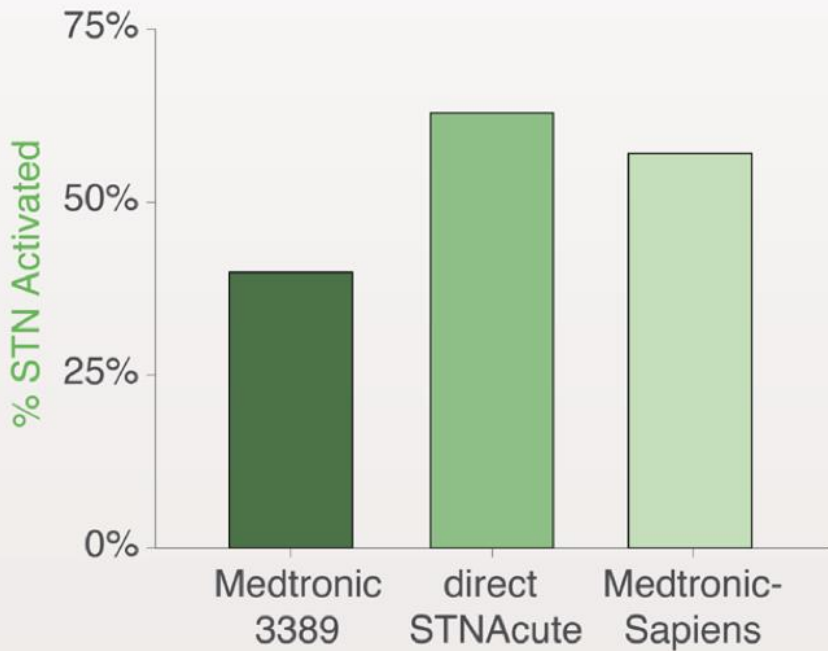
## A Optimal Settings for STN Center Placement



## Optimal Settings for Lateral Placement

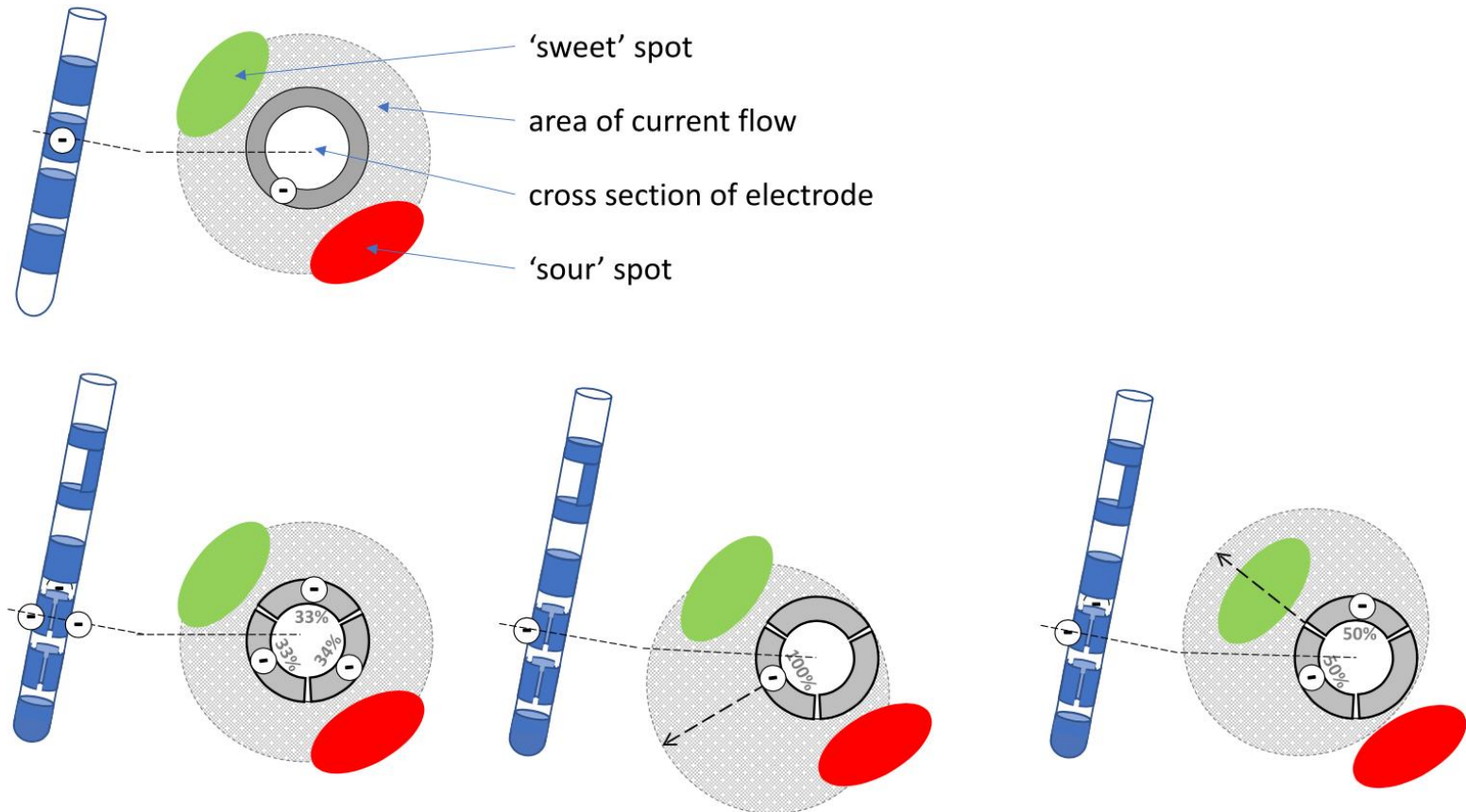


## B



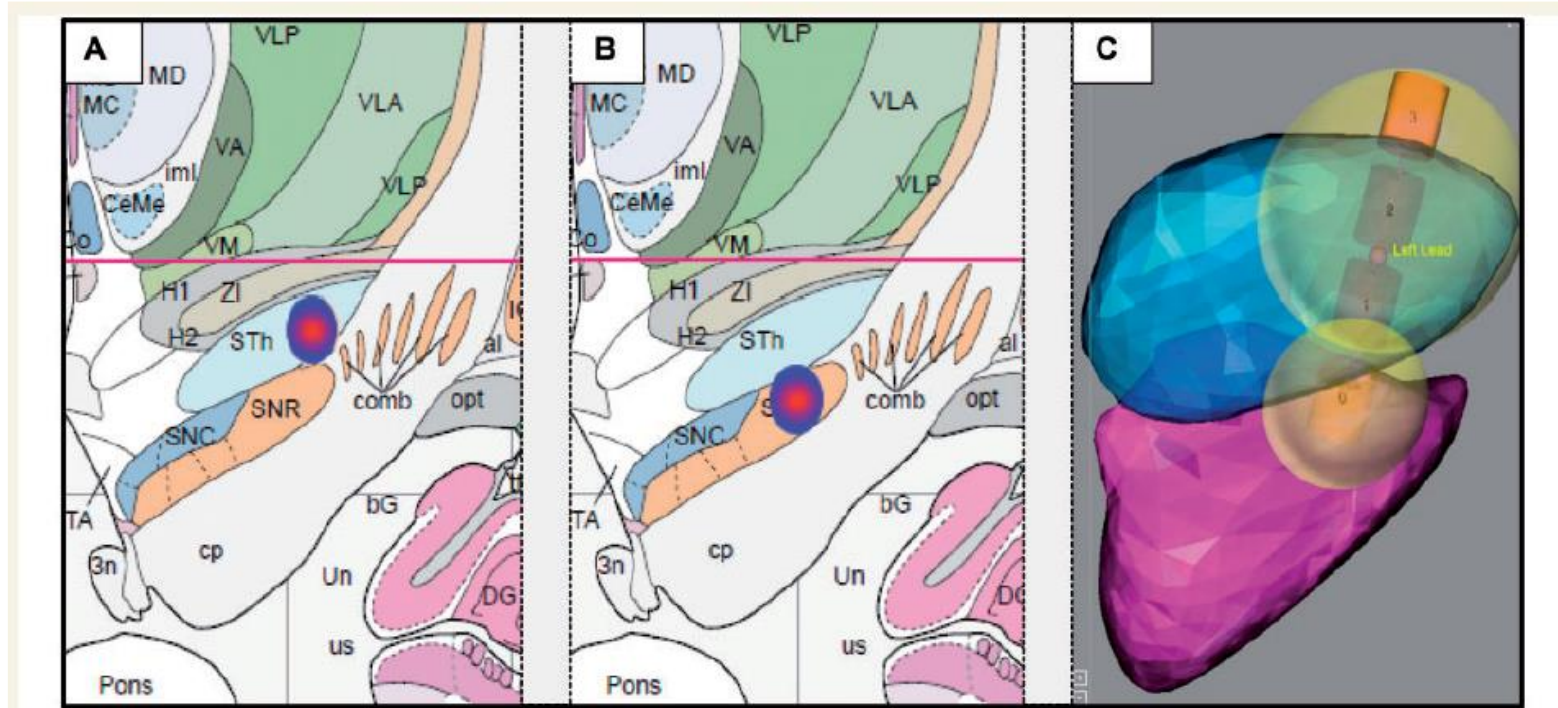
Anderson DN et al. 2018

- To avoid side effects from the stimulation, clinical evaluation might be enough to decide the direction of stimulation
- However, to maximize the benefits, understanding the right spot in the target is important



Steigerwald F et al. 2019

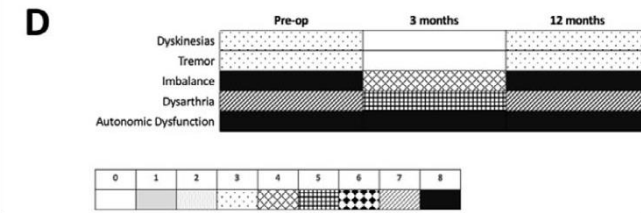
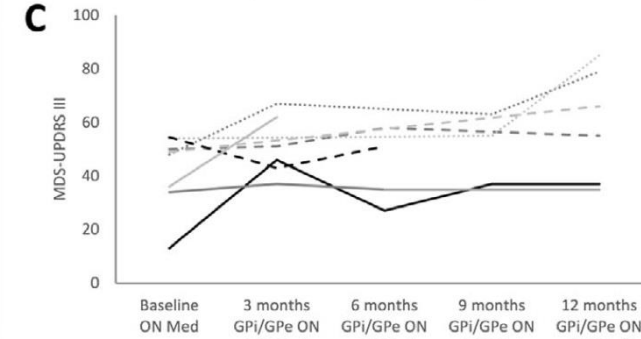
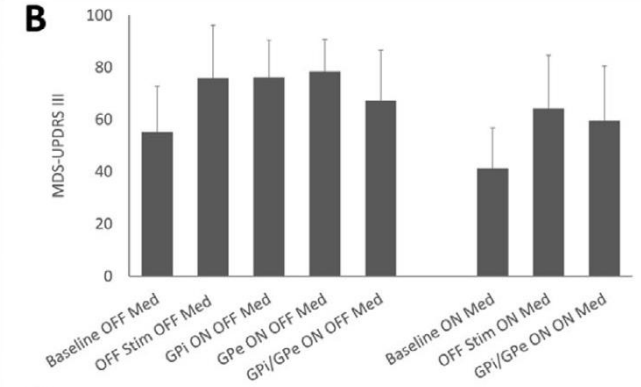
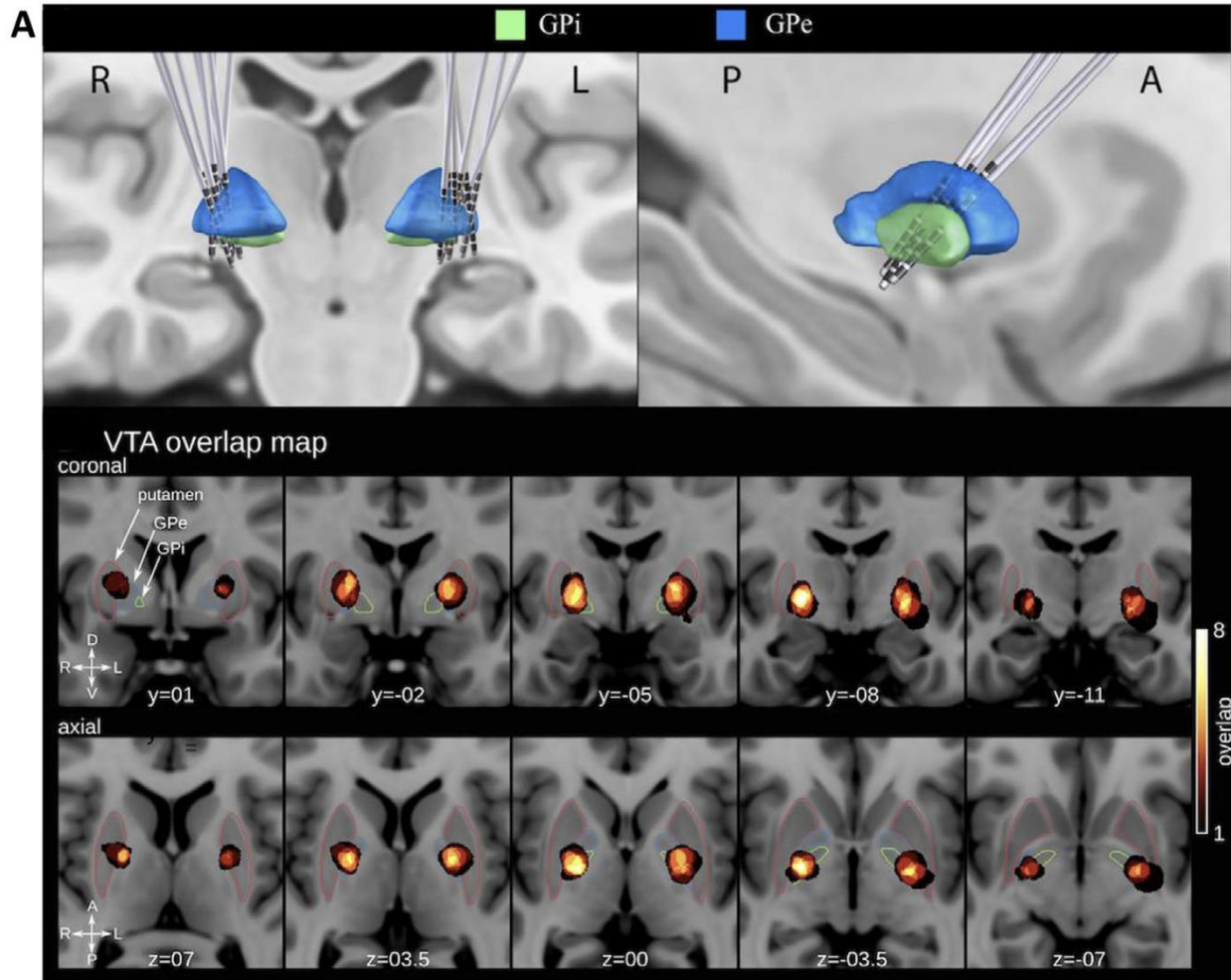
# Combined with Nigral Stimulation



**Figure 2** Localization of active electrode contacts of (A) dorsolateral STN and (B) dorsolateral SNr. Coordinates relative to the mid-commissural point (MCP) were: left STN  $-11.4 \pm 0.8$ ,  $-0.9 \pm 2.0$ ,  $-3.0 \pm 1.7$ ; right STN  $13.5 \pm 1.1$ ,  $-0.5 \pm 1.7$ ,  $-2.2 \pm 1.5$ ; left SNr  $-10.0 \pm 0.9$ ,  $-3.4 \pm 2.1$ ,  $-6.4 \pm 1.8$ ; right SNr  $12.1 \pm 1.3$ ,  $-3.3 \pm 1.7$ ,  $-5.8 \pm 1.5$  (x, y, z; x = medio-lateral, y = antero-posterior, z = rostro-caudal). Electrode coordinates (mean  $\pm$  standard deviation in x- and y-direction) are visualized in coronal view on the Atlas of the Human Brain with permission (Mai *et al.*, 2007). (C) An additional illustrative image of electrode localization including a simulation on volume of tissue activated was kindly provided by Medtronic based on work by Yelnik *et al.* (2007) (atlas) and D'Haese *et al.* (2012) (atlas and algorithms).

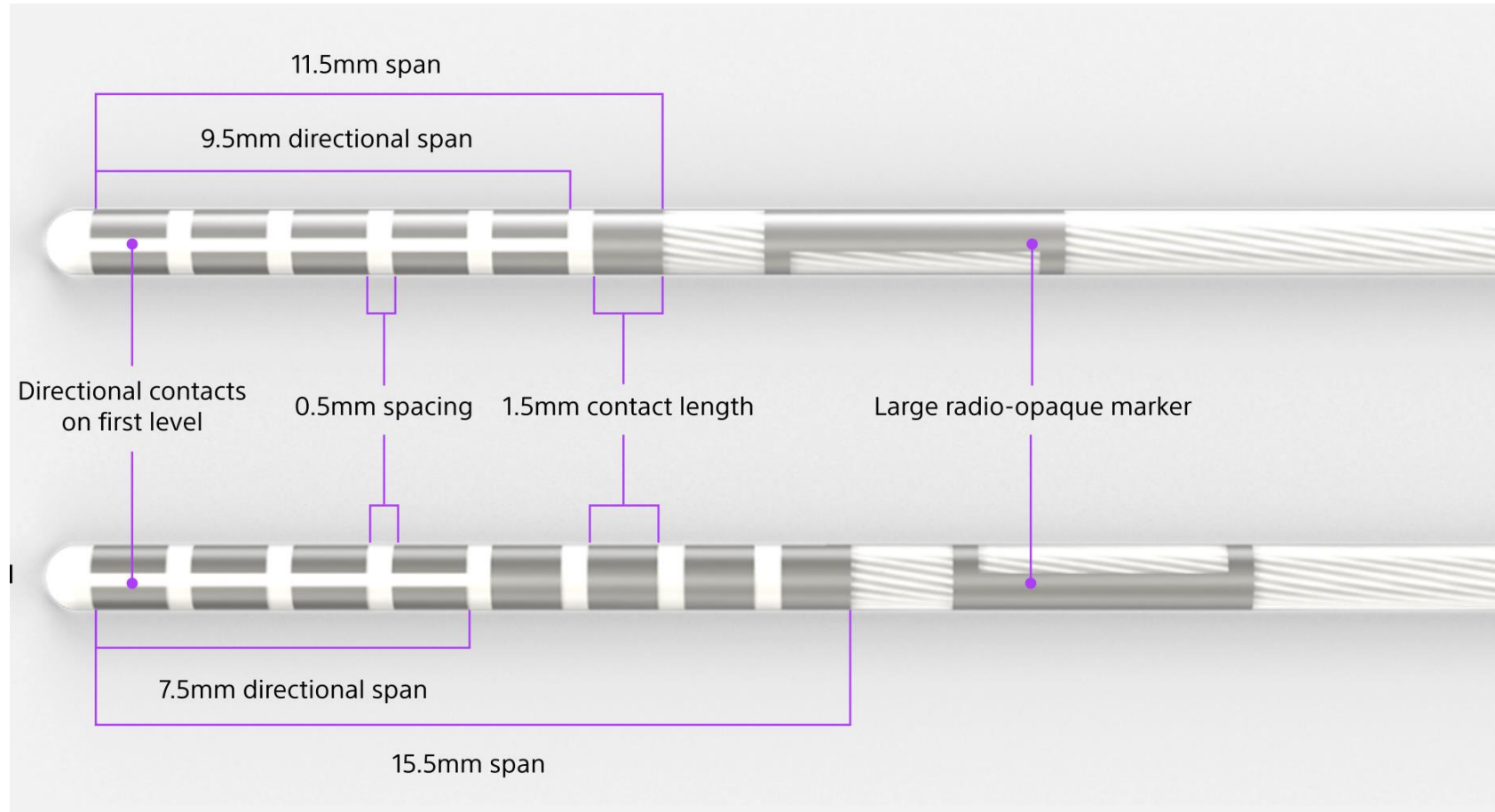
Weiss D et al. 2013

# Additional GPe stimulation

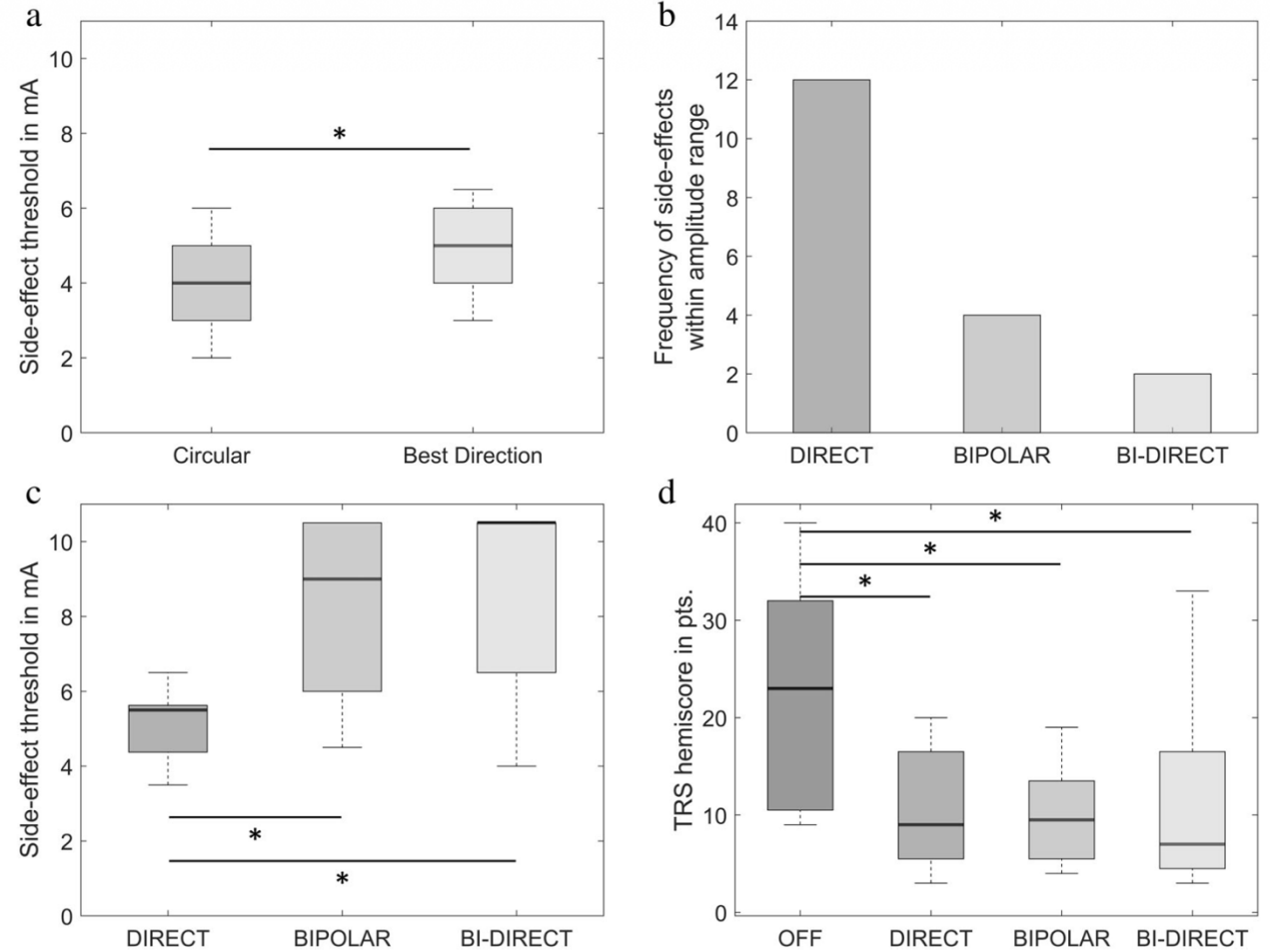
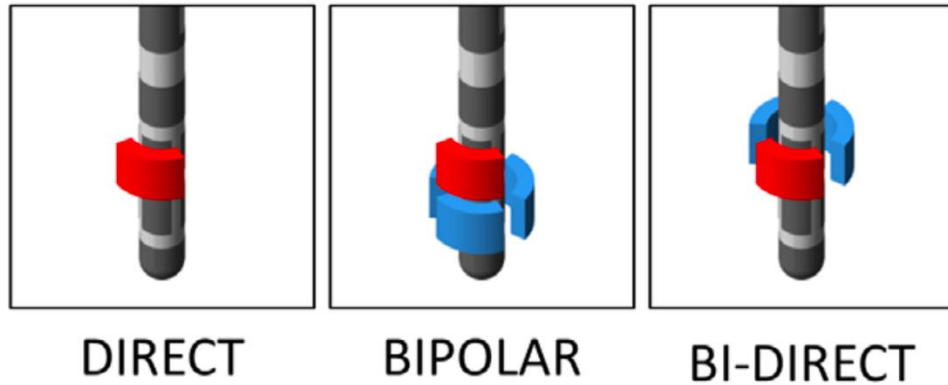


Di Luca D et al. 2023

# More Available in the Near Future



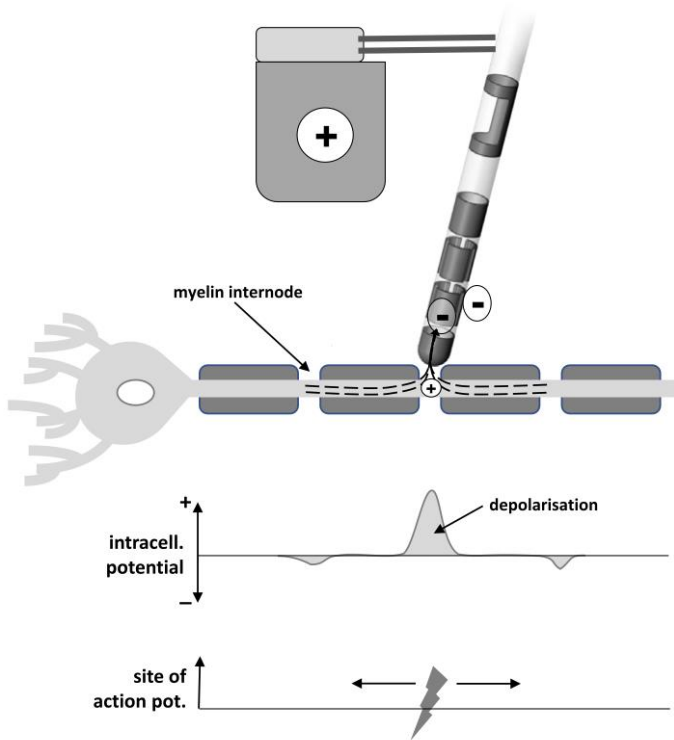
# Bipolar directional stimulation (Anodic block)



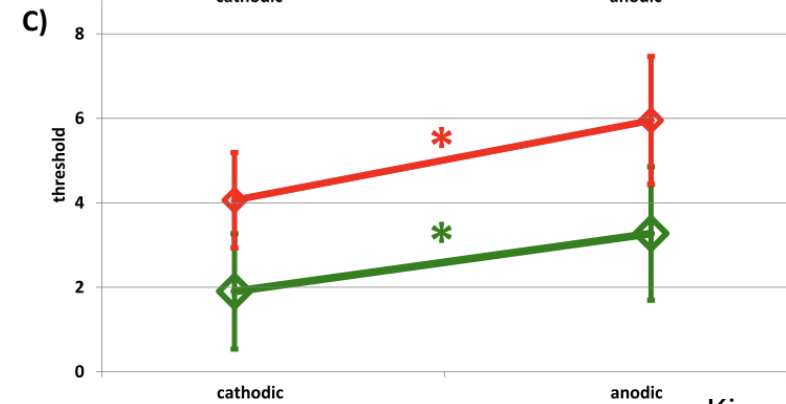
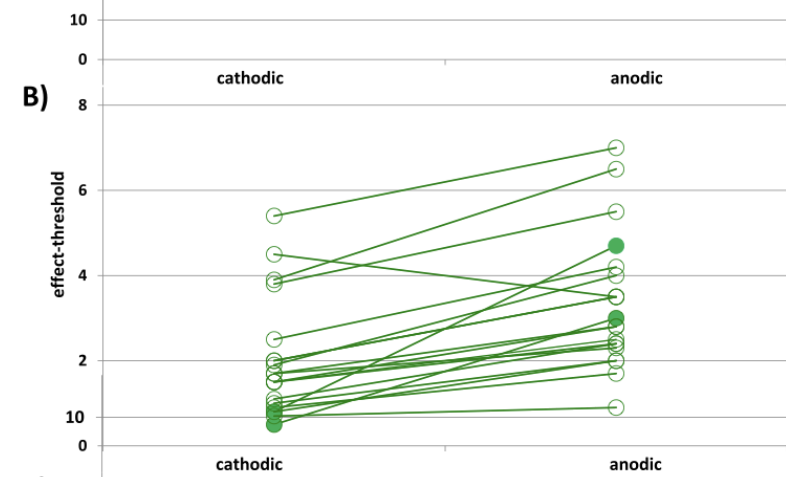
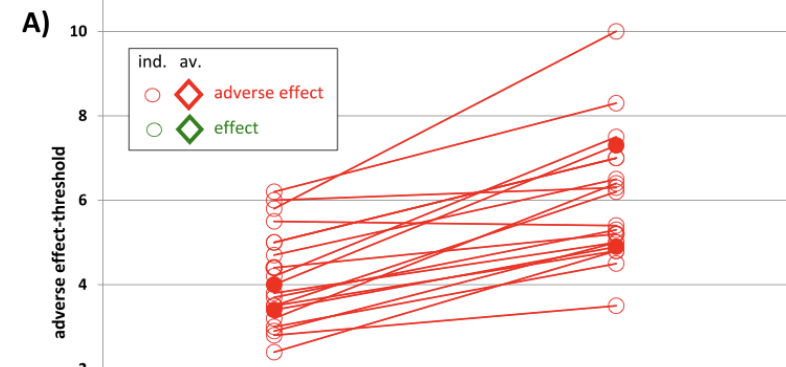
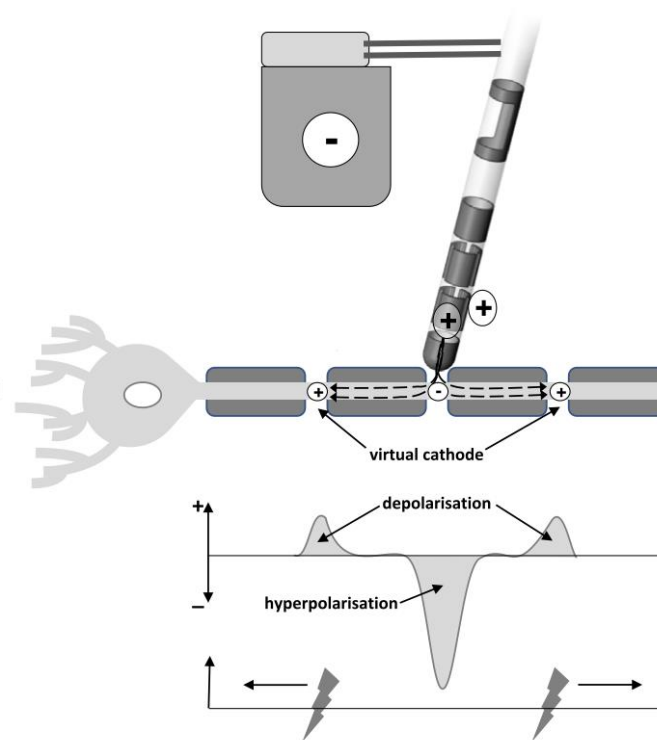
Steffen JK et al. 2020

# Anodic stimulation

A) cathodic stimulation



B) anodic stimulation



Kirsch AD et al. 2018

# Updates in DBS

- Electrodes
- Implatable Pulse Generator (IPG) or battery
- Programmers
- Surgery

# Updates in IPG



Model	Medtronic Activa PC	Medtronic Activa RC	Medtronic Activa SC	Medtronic Percept PC	Medtronic Percept RC
No. of channels	2	2	1	2	
Weight (gram)	67	40	44	61	
Size (mm)	65×49×15	54×54×9	55×60×11	68×51×12	
RC	No	Yes	No	No	YES
Freq. range (Hz)	2–250	2–250	3–250	2–250	
Pulse width (µs)	60–450	60–450	60–450	20–450	
TF	IL	IL	IL	IL	
CF	No	No	No	YES	YES
Directional lead	No	No	No	YES	YES
MRI safety	C	C	C	3T	3T
LFP sensing	No	No	No	Yes	

Sarica C et al. 2021

# Updates in IPG



Model	Boston Scientific Vercise PC	Boston Scientific Vercise Gevia	Boston Scientific Vercise Genus P8/P16	Boston Scientific Vercise Genus P8/P16
No. of channels	2	2	1/2	1/2
Weight (gram)	55	26	58	58
Size (mm)	71×50×11	51×46×11	72×50×12	72×50×12
RC	No	Yes	No	No
Freq. range (Hz)	2–255	2–255	2–255	2–255
Pulse width (µs)	10–450	20–450	20–450	20–450
TF	A	A	A	A
CF	MICC	MICC	MICC	MICC
Directional lead	Yes	Yes	Yes	Yes
MRI safety	U	C	C	C
LFP sensing	No	No	No	No

Sarica C et al. 2021

# Updates in IPG



Model	St. Jude (Abbott) Infinity 5	St. Jude (Abbott) Infinity 7	Liberta RC
No. of channels	2	2	
Weight (gram)	49	58	
Size (mm)	56×50×13	67×50×14	
RC	No	No	YES
Freq. range (Hz)	2–240	2–240	
Pulse width (μs)	20–500	20–500	
TF	MSS	MSS	
CF	CA	CA	
Directional lead	Yes	Yes	
MRI safety	C	C	
LFP sensing	No	No	

Sarica C et al. 2021

# Local Field Potentials in Movement Disorders

Typical LFP frequency bands associated with symptoms in specific disease states.

	Delta (0-4 Hz)	Theta/Alpha (4-13 Hz)	Low Beta (13-20 Hz)	High Beta (20-35 Hz)	Gamma (35-250 Hz)
PD: Akinetic-Rigid symptoms			●	●	●
PD: Tremor symptoms		●			●
Essential Tremor		●	●	●	
Dystonia <sup>+</sup> (tonic)	●		●		● (60-90 Hz)
Dystonia <sup>+</sup> (phasic)		●	●		● (60-90 Hz)

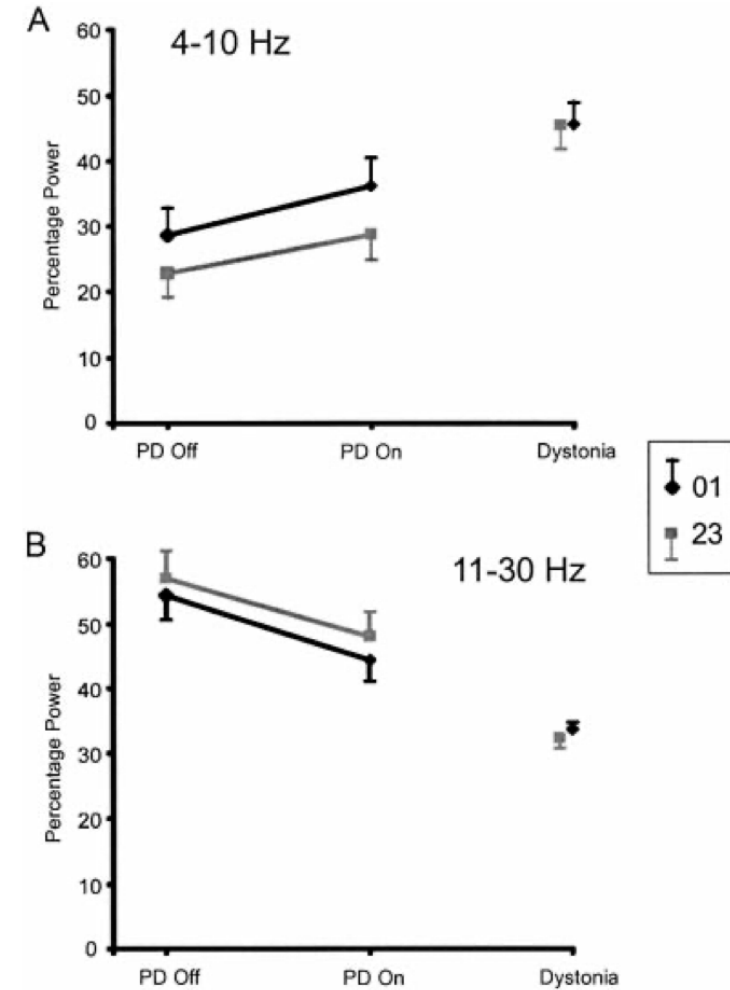
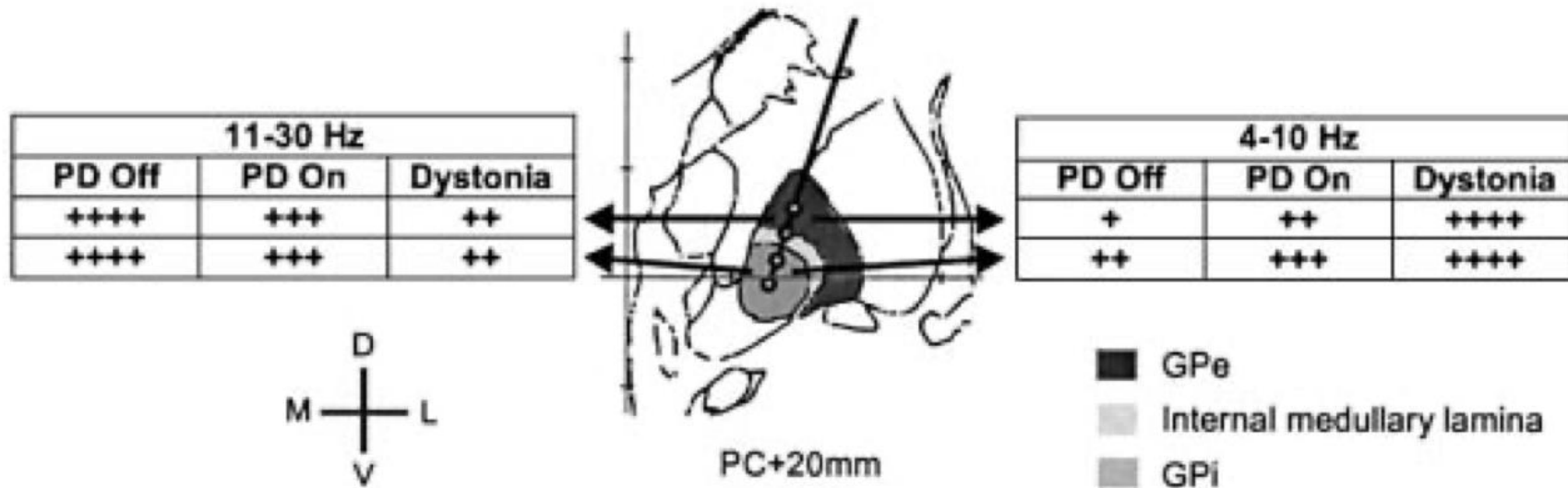
- likely association of LFP band to disease state (large body of literature supports findings)
- potential association of LFP band to disease state

Sirica D et al. 2021

# Targets and Local Field Potential

Aspect	STN LFPs	GPI LFPs
Dominant PD band	Prominent low beta (~13–30 Hz) peaks, tightly linked to akinetic-rigid features.	Alpha–beta peaks present; oscillatory signatures somewhat similar to STN but less extensively characterized.
Modulation by therapy	Beta power reduced by levodopa and STN-DBS; reduction scales with motor benefit.	Alpha/beta activity modulated by GPI-DBS; ERNA features relate to effective stimulation sites.

# Pallidal LFP in PD and dystonia



Silberstein P et al. 2003

# MRI compatibility

**TABLE 2** | Overview of IPG systems capable of continuous stimulation, with their features and stimulation parameters.

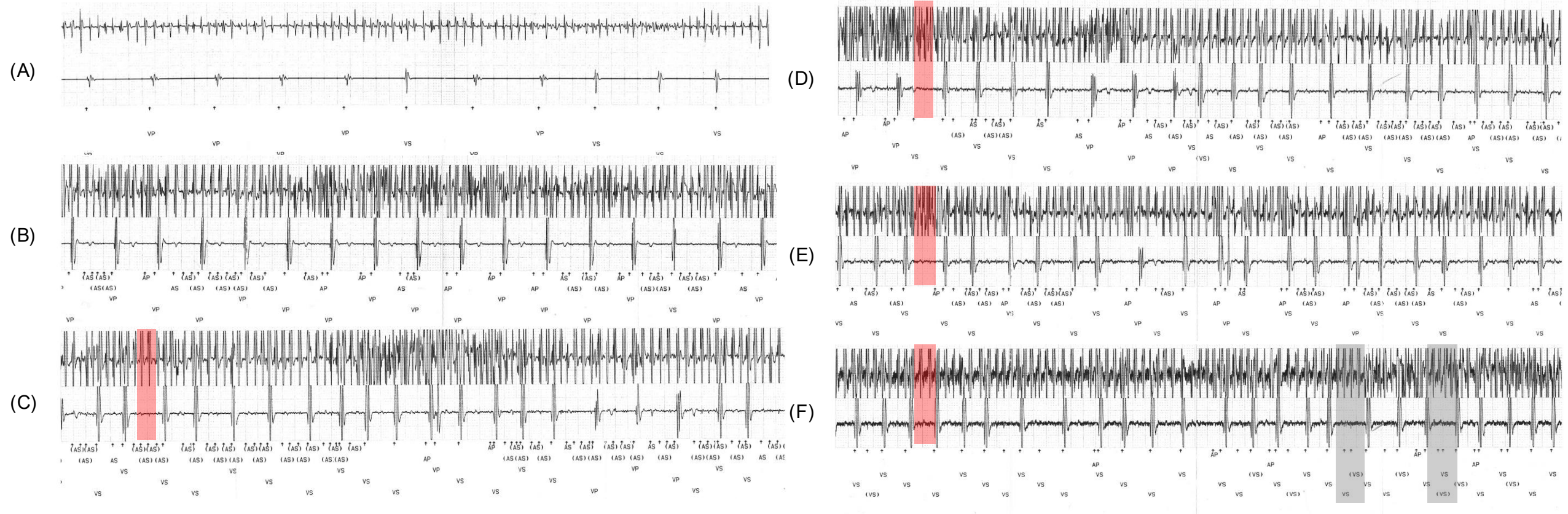
Company	IPG	Rechargeable?	Lead Compatibility	Frequency (Hz)	Pulse Width ( $\mu$ s)	MRI Compatibility?
Medtronic	Activa-PC	N	Dual	2–250	60–450	Conditionally safe
	Activa-RC	Y	Dual	2–250	60–450	Conditionally Safe
	Activa-SC	N	Single	3–250	60–450	Conditionally safe
	Percept	N	Dual	2–250	20–450	Conditionally safe
Abbott	Infinity 5	N	Single	2–240	20–500	Conditionally safe
	Infinity 7	N	Dual	2–240	20–500	Conditionally safe
Boston	Vercise-PC	N	Dual	2–255	10–450	No
	Vercise-RC	Y	Dual	2–255	10–450	No
	Gevia	Y	Dual	2–255	20–450	Conditionally safe
	Genus	N	Dual	2–255	20–450	Conditionally safe
PINS	G102	N	Dual	2–250	30–450	Unknown
	G102R	Y	Dual	2–250	30–450	Unknown
	G101A	N	Single	2–240	30–450	Unknown
SceneRay	1180	N	Dual	1–1600	60–960	Unknown
Newronika	AlphaDBS	Y	Dual	Unknown	<360	Unknown

Frey J et al. 2022

# Illustrative Case. F/74 with bilateral STN DBS

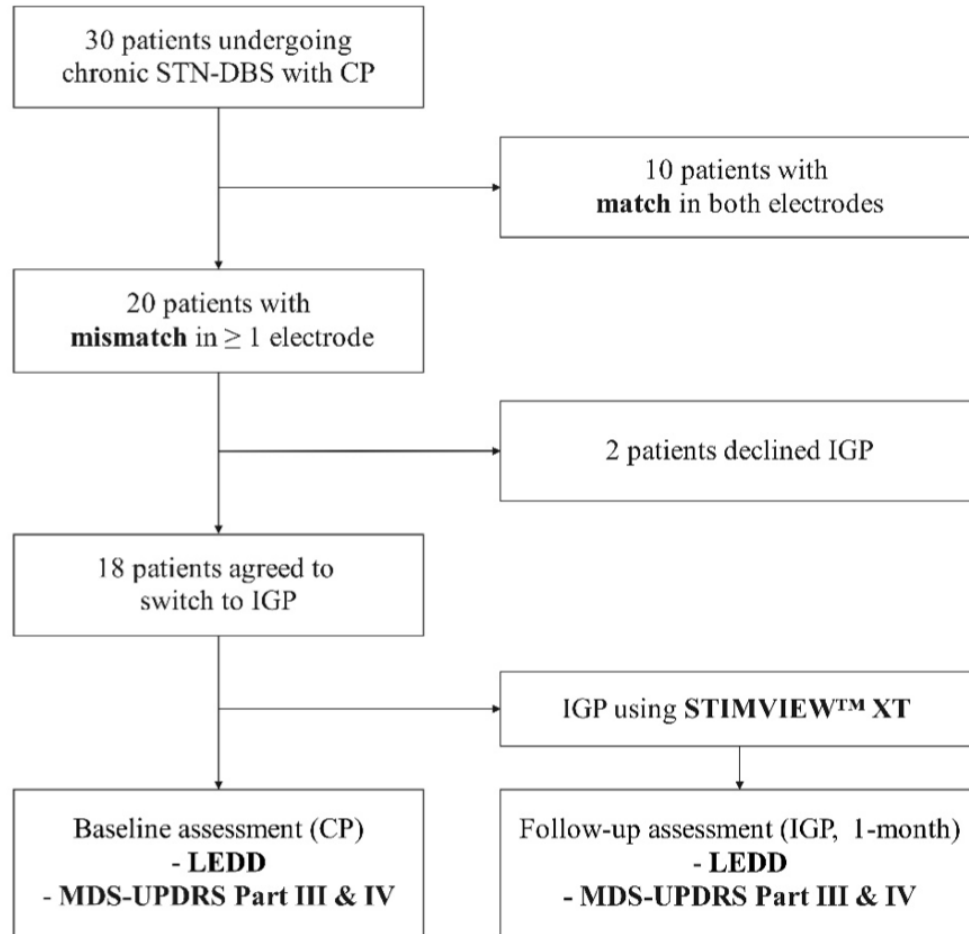
- Her motor symptoms were well-controlled with bilateral STN DBS, but her cognition and balance were getting worse slowly
- Visited ER with right hemiparesis and aphasia due to hyperacute stroke in left MCA territory
- Took 3T MRI for revascularization and performed IA thrombolysis, but failed
- Her IPG was depleted after taking MRI → considered changing IPG but caregivers denied

# Device Interaction



Ha J et al. 2024

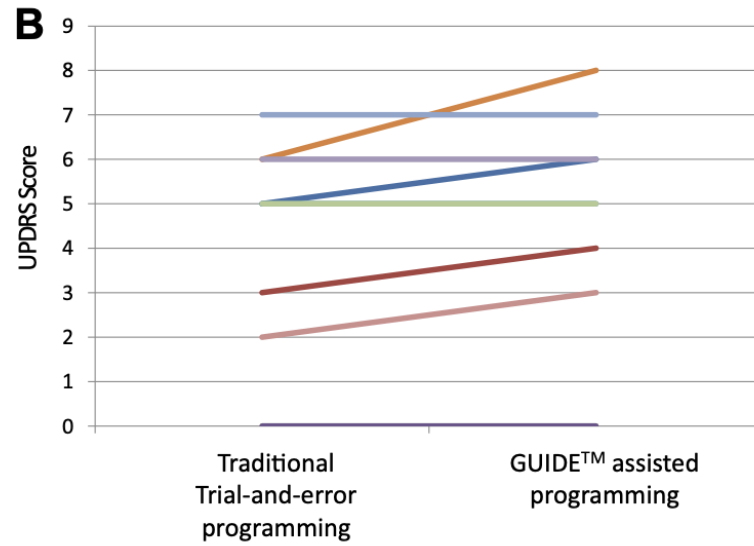
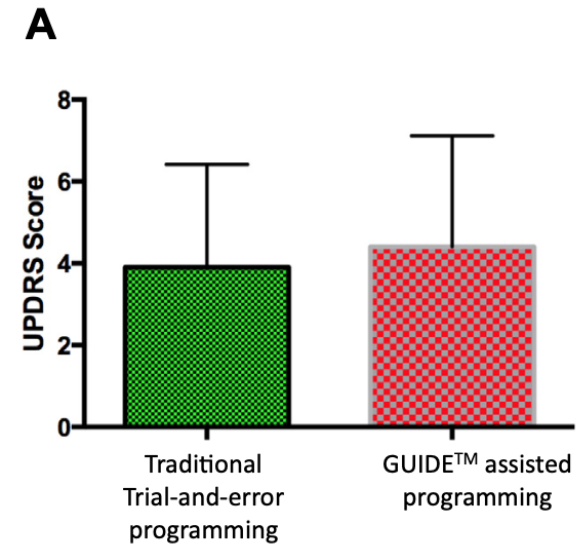
# More Chance for Improvement



	Responders (n=11)	Non-responders (n=7)	<i>p</i> -value
<b>Age, years</b>	61.1 ± 7.7	58.4 ± 9.6	0.54
<b>Sex, male (%)</b>	8 (72.7)	4 (57.1)	0.63
<b>Disease duration, years</b>	13.4 ± 5.9	14.0 ± 4.7	0.82
<b>MDS-UPDRS III (pre)</b>	23.8 ± 20.5	15.9 ± 5.2	0.25
<b>MDS-UPDRS IV (pre)</b>	3.4 ± 2.2	1.3 ± 1.7	<b>0.04</b>
<b>LEDD (pre), mg</b>	719.4 ± 338.4	554.3 ± 303.3	0.30
<b>Bilateral IGP application, n (%)</b>	10 (90.9)	5 (71.4)	0.53
<b>Electrode discrepancies</b>			
<b>Level only, n (%)</b>	1 (9.1)	1 (14.3)	1.00
<b>Direction only, n (%)</b>	3 (27.3)	1 (14.3)	1.00
<b>Level and direction, n (%)</b>	7 (63.6)	5 (71.4)	1.00

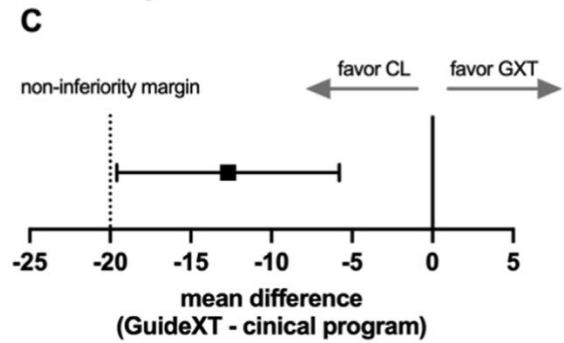
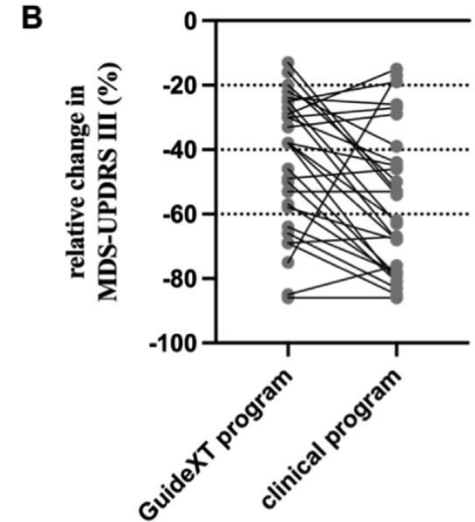
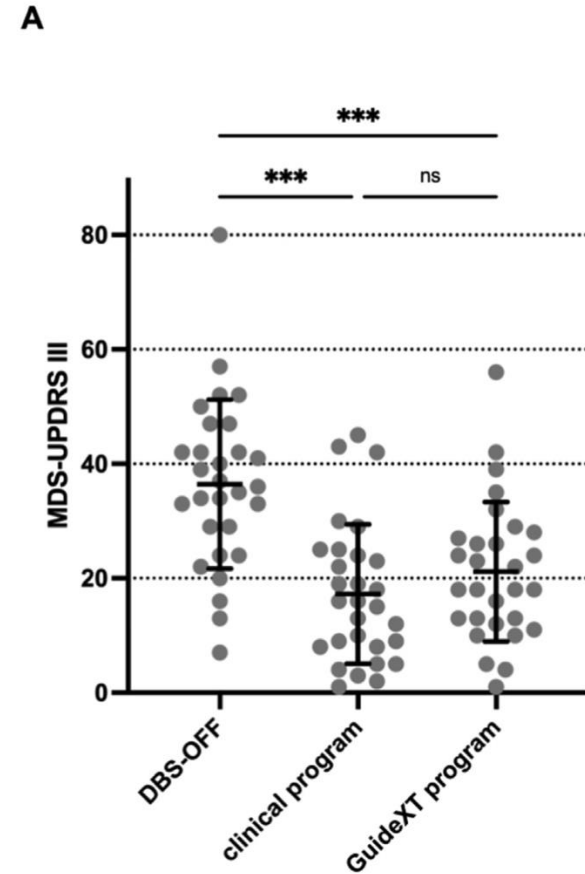
Manuscript in submission

# Image-guided Programming



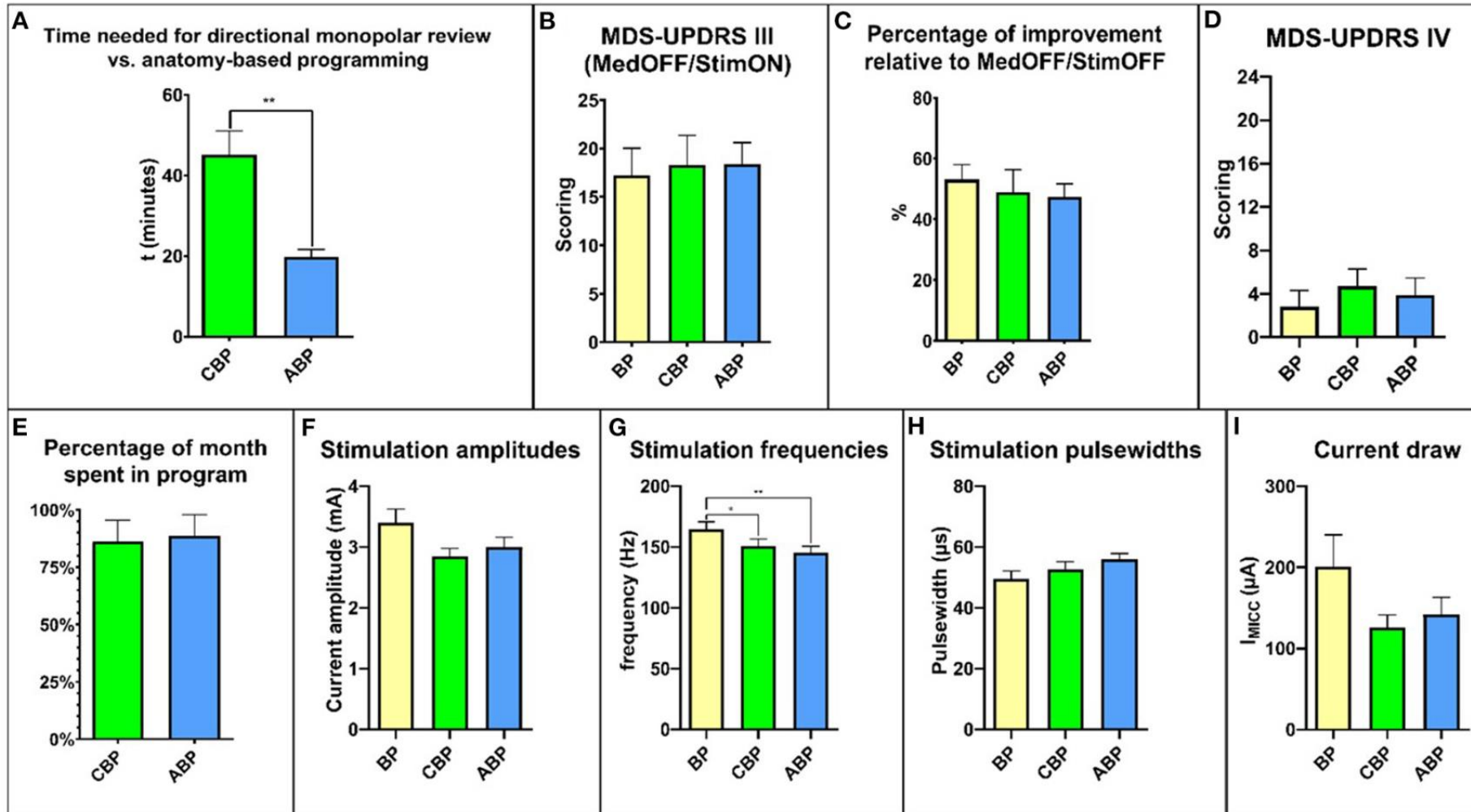
individual scores. UPDRS, Unified Parkinson's Disease Rating Scale.

**Figure 1.** Final Unified Parkinson's Disease Rating Scale scores (subitems 20–26) on stimulation with the 2 approaches: **(A)** mean values  $\pm$ SD and **(B)** patients'



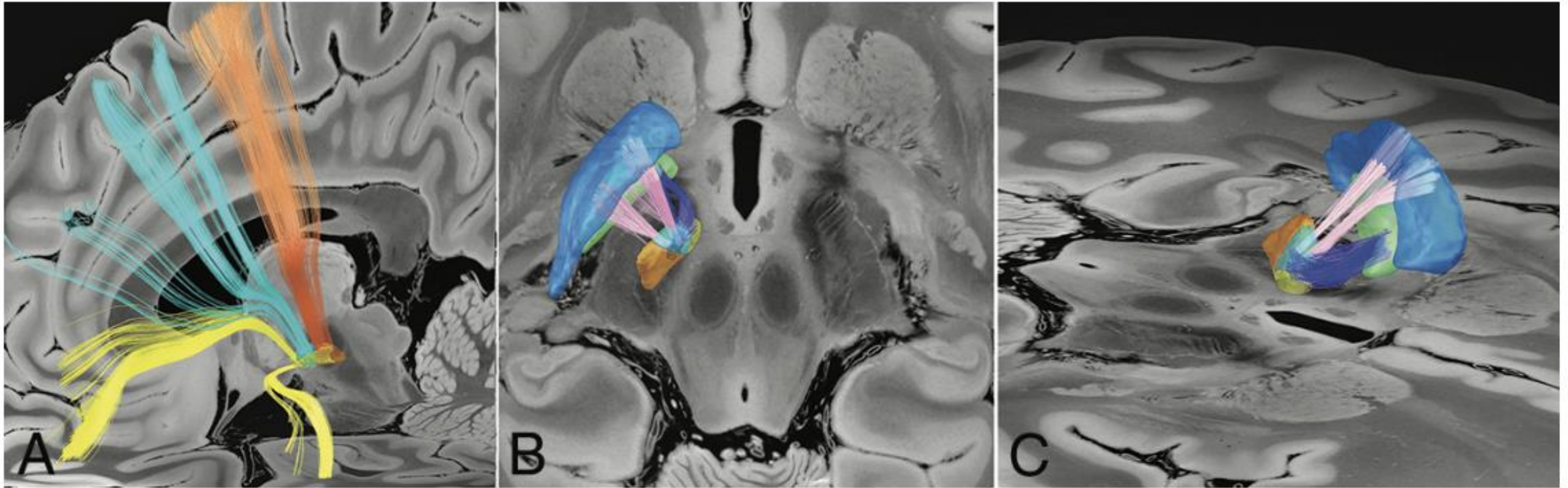
Pavese N et al. 2019, Waldthaler J et al. 2021

# Image-guided Programming



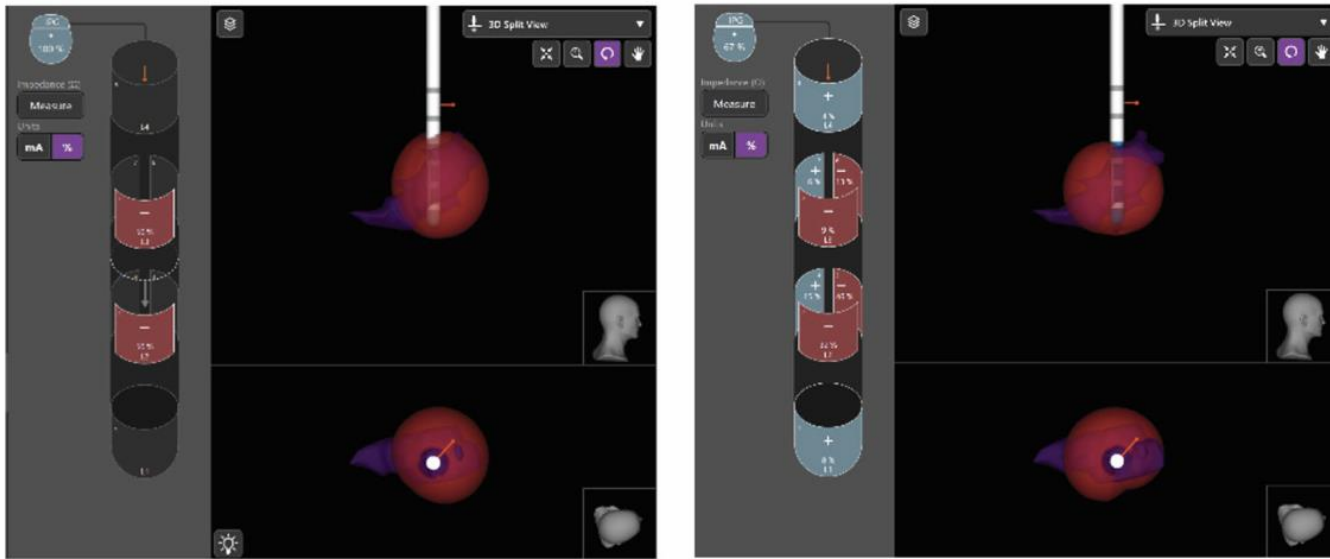
Lange F et al. 2021

# Sweet Spot in Parkinson's disease



Middlebrooks EH et al. 2020

A



### Create Illumina 3D™ Simulation

Select a Target (STN, GPi or Vim) per Approved Indications For Use (IFU). Optionally select Avoidance Region(s).

#### Select Target Region

Capsula Interna Left

STN Left Anterior

STN Left Posterior

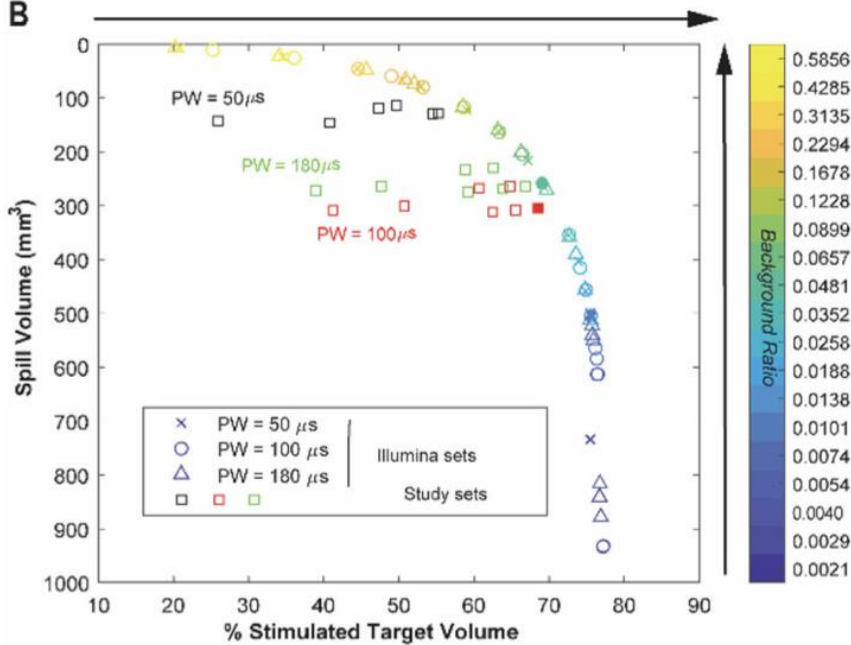
#### Select Avoid Region(s)

Capsula Interna Left

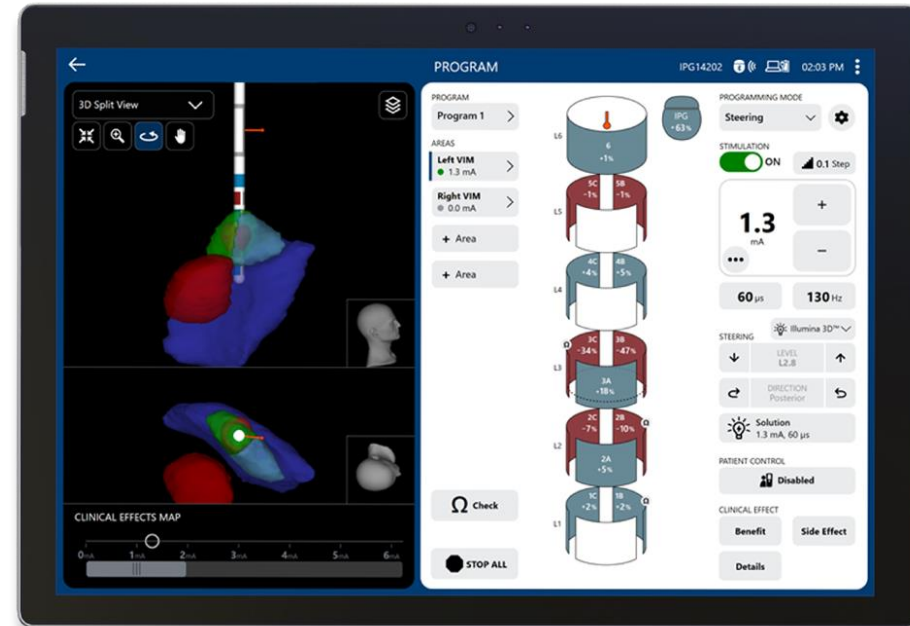
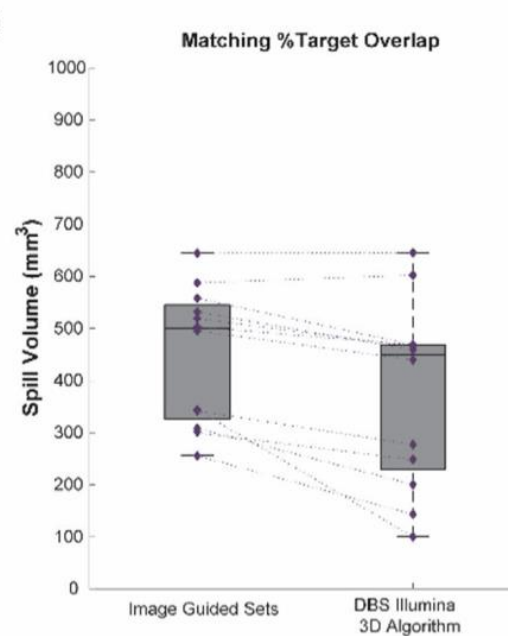
STN Left Anterior

STN Left Posterior

B



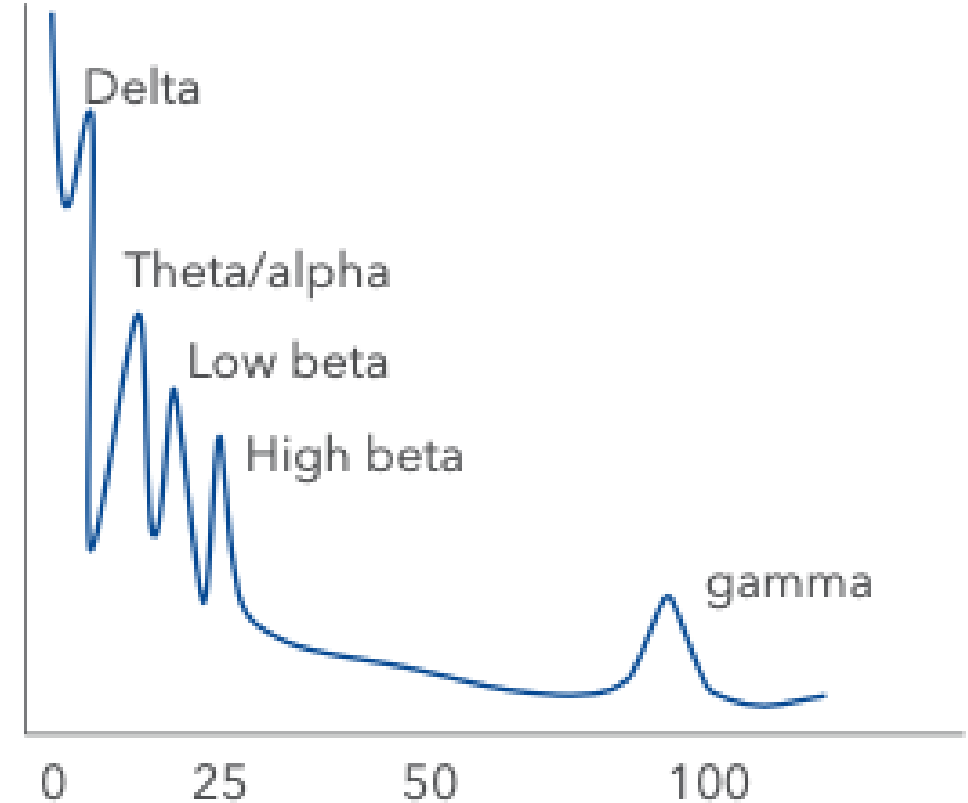
C



Malekmohammadi M et al. 2022

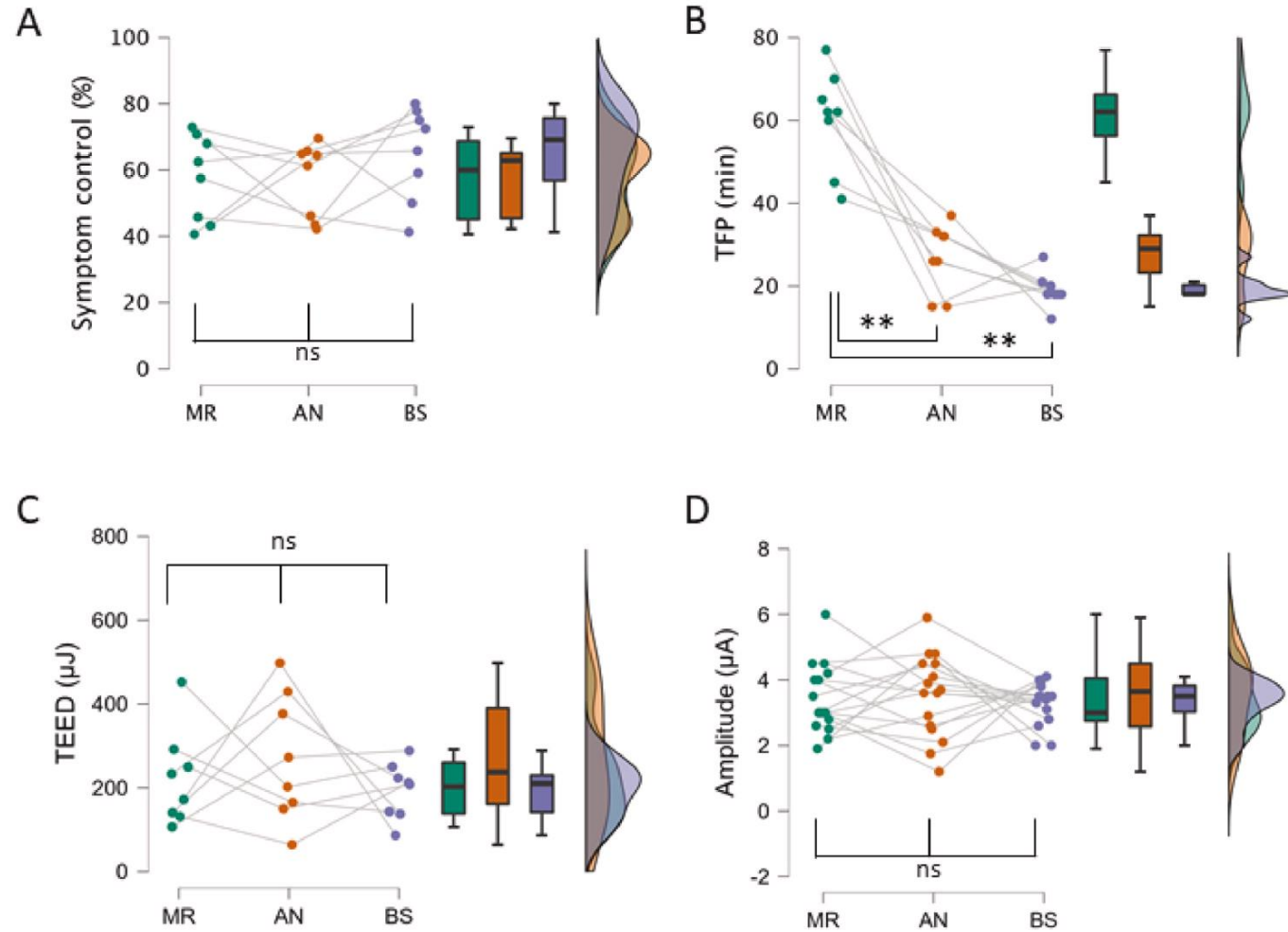
# Local Field Potentials (LFP)

- LFPs represent the summed electrical activity from local neuronal transmembrane currents around an electrode
- Important factors that contribute to the LFP include the cellular and synaptic cellular architecture and the synchrony of the current sources
- LFPs have been characterized into frequency bands (approximate range, Hz)



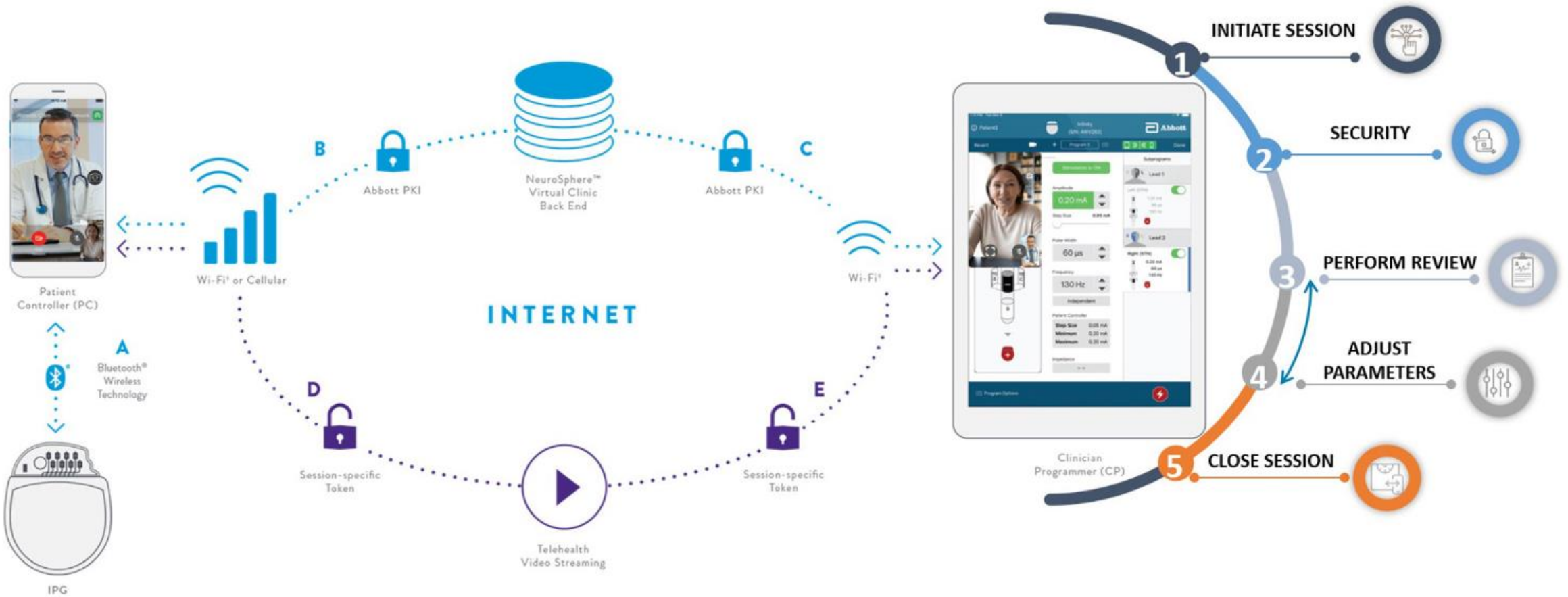
Hanslmayr S et al. 2012

# LFPs base Programming



Binder T et al. 2023

# Synchronous Telemedicine in DBS

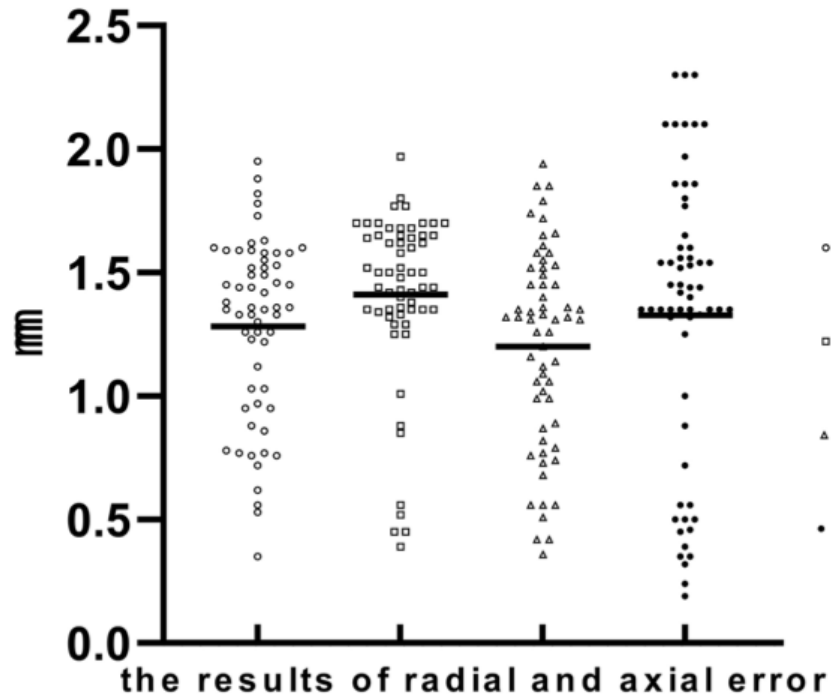


Merola A et al. 2021

## DBS and telemedicine.

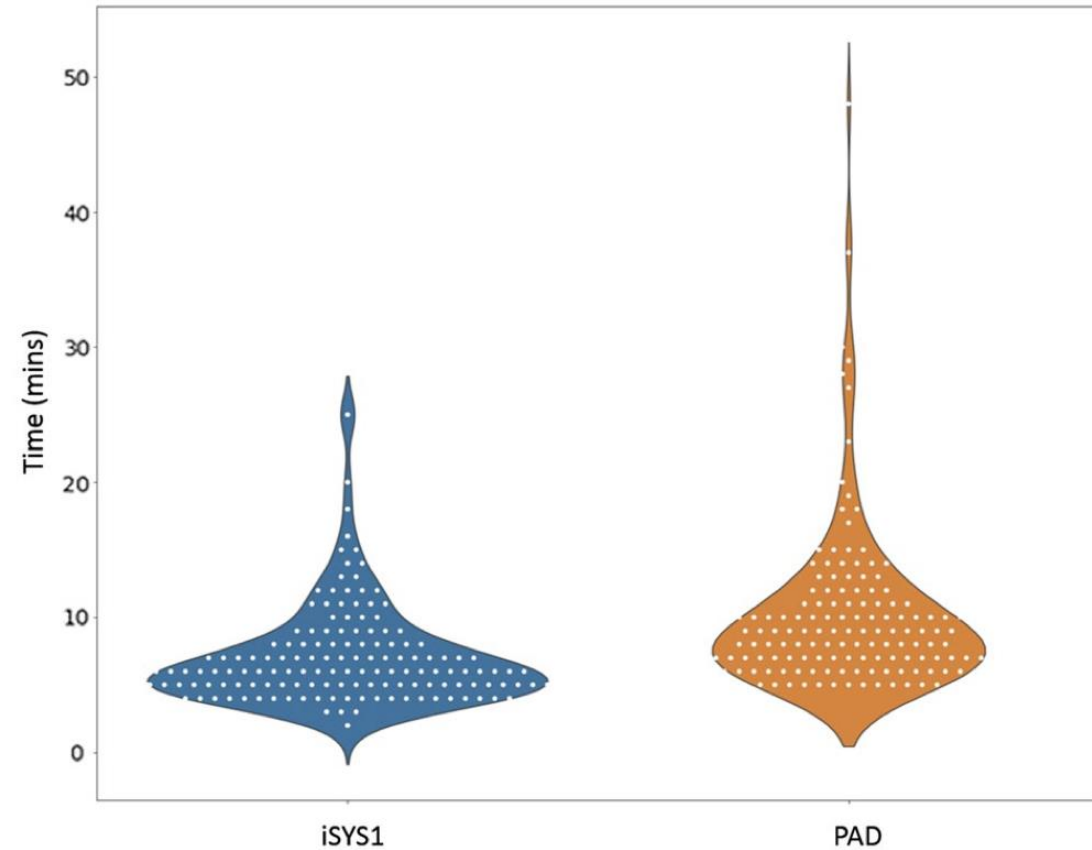
Type	Definition	Comments	Example
Asynchronous	Delivering care without face-to-face contact Transfer of information occur at different time	Easy to implement Allows flexibility Need less complicated technology	Programming adjustment recommendations on Email, secured message or telephone based on patients' feedback. All DBS systems using PC
Synchronous	Real-time, face-to-face interaction between patient and clinician	Allows real-time assessment and discussion Need coordination for scheduling Requires complicated technology	Self-programming with patient controller under the supervision of clinician. Remote tele-programming and video conferencing – Abbott Neurosphere™ Virtual Clinic platform
Remote patient monitoring	Utilize technology to gather patient data outside of clinic	Permits prolonged monitoring of symptoms Allows objective assessment remotely	Wrist-worn devices Central sensing of brain signals – Percept™ PC DBS device by Medtronic

# Robotic Surgery in DBS



- The average radial error of the robot
- The average radial error of conventional surgery
- △ The average axial error of the robot
- The average axial error of conventional surgery

Comparison of electrode insertion times between implantation methods



Ma FZ et al. 2022, Vakharia VN et al. 2021

# Awake vs. Asleep DBS

TABLE 3 Comparison of motor outcomes.

Motor outcome	STIM state	MED-OFF							MED-ON						
		Awake group		Asleep group		Improvement			Awake group		Asleep group		Improvement		
		Baseline	1 year	Baseline	1 year	Awake group	Asleep group	<i>p</i>	Baseline	1 year	Baseline	1 year	Awake group	Asleep group	<i>p</i>
MDS-UPDRS III	off		50.10 ± 12.45		55.28 ± 16.12	-0.04 ± 0.36	-0.07 ± 0.26	0.453 <sup>c</sup>		25.71 ± 14.40		29.92 ± 15.83	-0.60 ± 1.38	-0.46 ± 0.68	0.460 <sup>c</sup>
	on	50.57 ± 11.54	28.24 ± 10.14	53.36 ± 15.95	26.64 ± 11.44	0.43 ± 0.21	0.47 ± 0.22	0.494 <sup>a</sup>	19.05 ± 7.22	15.81 ± 7.96	21.72 ± 8.87	16.84 ± 8.83	0.10 ± 0.52	0.19 ± 0.40	0.530 <sup>c</sup>
Tremor	off		6.43 ± 4.66		7.56 ± 6.37	-0.35 ± 2.12	-0.12 ± 0.88	0.605 <sup>c</sup>		1.57 ± 2.11		3.08 ± 4.98	0.40 ± 0.53	-1.27 ± 3.35	0.168 <sup>c</sup>
	on	7.38 ± 5.50	2.86 ± 3.37	7.52 ± 6.06	2.24 ± 3.11	0.66 ± 0.37	0.64 ± 0.48	0.846 <sup>c</sup>	1.19 ± 1.54	1.00 ± 1.38	1.24 ± 1.48	0.36 ± 0.95	0.22 ± 0.75	0.63 ± 0.72	0.087 <sup>c</sup>
Rigidity	off		10.90 ± 3.51		11.00 ± 2.87	0.01 ± 0.38	-0.02 ± 0.30	0.860 <sup>c</sup>		6.19 ± 3.71		6.04 ± 3.81	-0.10 ± 0.81	-0.10 ± 1.00	0.945 <sup>c</sup>
	on	11.29 ± 2.22	6.10 ± 2.97	11.12 ± 2.80	5.00 ± 3.63	0.46 ± 0.27	0.54 ± 0.33	0.361 <sup>a</sup>	5.95 ± 3.35	3.86 ± 3.10	6.20 ± 3.14	3.36 ± 3.38	0.23 ± 0.74	0.50 ± 0.49	0.127 <sup>c</sup>
Akinesia	off		24.00 ± 7.48		26.12 ± 6.50	-0.13 ± 0.53	-0.15 ± 0.29	0.871 <sup>a</sup>		13.62 ± 8.66		14.24 ± 6.84	-0.66 ± 1.28	-0.47 ± 0.72	0.757 <sup>c</sup>
	on	22.90 ± 6.57	14.10 ± 4.83	23.48 ± 6.51	13.60 ± 5.38	0.34 ± 0.31	0.39 ± 0.26	0.552 <sup>a</sup>	9.36 ± 3.74	8.14 ± 4.35	10.44 ± 4.59	9.40 ± 4.43	0.03 ± 0.58	0.06 ± 0.34	0.708 <sup>c</sup>
Axial symptoms	off		8.76 ± 3.94		11.20 ± 5.80	-0.09 ± 0.59	-0.04 ± 0.47	0.766 <sup>c</sup>		4.33 ± 3.34		5.64 ± 4.80	-1.82 ± 3.42	-0.84 ± 1.22	0.748 <sup>c</sup>
	on	9.00 ± 3.80	5.19 ± 2.71	11.24 ± 4.73	5.80 ± 3.76	0.37 ± 0.36	0.45 ± 0.35	0.501 <sup>c</sup>	2.55 ± 2.22	2.81 ± 2.29	3.84 ± 2.78	3.72 ± 3.16	-0.58 ± 1.61	-0.28 ± 1.35	0.739 <sup>c</sup>
H&Y stage	off		3.10 ± 0.70		3.24 ± 0.72	-0.10 ± 0.27	-0.02 ± 0.21	0.982 <sup>d</sup>		2.38 ± 0.67		2.48 ± 0.71	-0.28 ± 0.48	-0.01 ± 0.30	0.865 <sup>d</sup>
	on	2.90 ± 0.70	2.33 ± 0.48	3.20 ± 0.41	2.28 ± 0.54	0.16 ± 0.24	0.28 ± 0.17	0.521 <sup>d</sup>	2.05 ± 0.67	2.10 ± 0.63	2.52 ± 0.51	2.00 ± 0.65	-0.14 ± 0.51	0.17 ± 0.31	0.454 <sup>d</sup>

<sup>a</sup>This variable was analyzed using the *t*-test,

<sup>b</sup>These variables were analyzed using the Mann-Whitney *U* test,

<sup>c</sup>*p* value of Covariance analysis after correction baseline.

# Anesthesia and Neurophysiology

**TABLE 2.** Summary of the Evidence of the Effect of Anesthetic Agents on Microelectrode Recordings During Deep Brain Stimulation Surgery

Parkinson Disease	Target	Dose	Firing Rate	Burst Discharge	Background Activity	Target Identification	Level of Evidence
Propofol	STN	≤ 1.5 mg/kg/h	≈	≈	≈	+	C
Dexmedetomidine	STN	≤ 0.6 μg/kg/h	≈	≈	≈	+	B
Volatile anesthetics							
Desflurane	STN	≤ 0.6 MAC	≈	?	≈	+	C
Sevoflurane	STN	1.0%-2.5%\$	?	?	?	+	C
Dystonia							
Propofol	GPI	3-6 mg/kg/h	↓	↑	?	+/-	C
Volatile anesthetics							
Desflurane	GPI/GPe	1.5%-4.5%\$	↓	?	↓	?	C
Sevoflurane	GPI	1.5%-2.5%\$	↓	↓	?	?	C
Isoflurane	GPI/GPe	0.3%-0.5%\$	↓	↓	?	?	C

Recommendations are classified according to the criteria of the Oxford Centre for Evidence-based Medicine (far right column).<sup>7</sup>

A, consistent level 1 studies; B, consistent level 2 or 3 studies or extrapolations from level 1 studies; C, level 4 studies or extrapolations from level 2 or 3 studies; D, level 5 evidence or troublingly inconsistent or inconclusive studies of any level.

↓ indicates decrease; ↑, increase; +/-, probably; +, possible; \$ end-tidal concentration; ?, no available literature; ≈, no clear effect; GPe, external globus pallidus; GPI, internal globus pallidus; MAC, minimum alveolar concentration; MER, microelectrode recordings; STN, subthalamic nucleus.

# Age limits for DBS

Clinical outcomes before and 6 m after DBS in both younger and older groups.

	Younger group			Older group			<i>p</i> -value‡
	Pre-DBS	Post-DBS	<i>p</i> -value*	Pre-DBS	Post-DBS	<i>p</i> -value†	
MMSE	28.0 (26.0–29.0)	28.0 (25.0–29.0)	0.092	27.0 (24.5–29.0)	27.5 (24.0–28.5)	0.766	0.177
HY stage (ON)	2.0 (2.0–2.5)	2.0 (1.5–2.5)	0.424	2.0 (2.0–2.5)	2.0 (1.5–2.75)	0.5	0.624
UPDRS part 3 (ON)	17.0 (11.0–24.0)	13.8 (9.0–21.0)	0.001	21.0 (17.5–28.5)	15.0 (6.5–24.0)	0.012	0.087
UPDRS part 4							
A. Dyskinesias	2.5 (2.0–4.0)	0.5 (0.0–2.0)	< 0.001	2.0 (1.5-3.0)	0.5 (0.0–2.0)	0.01	0.369
B. Clinical fluctuations	3.0 (2.0–4.0)	0.5 (0.0–2.0)	< 0.001	3.0 (3.0-4.0)	2.0 (0.0–2.0)	< 0.001	0.312
C. Other complications	1.0 (0.0-1.0)	0.5 (0.0-1.0)	< 0.001	1.0 (0.0-2.0)	1.0 (0.0-2.0)	1	0.533
Total score	6.5 (5.0-8.0)	2.0 (1.0-4.0)	< 0.001	6.0 (5.0-8.5)	3.0 (2.0-5.0)	< 0.001	0.701

DBS, deep brain stimulation; MMSE, mini-mental status exam; HY stage, Hoehn Yahr stage; UPDRS, unified Parkinson's disease rating scale.

*p*-value\*, comparison between pre and post-DBS in the younger group by paired Students' *t*-test or Wilcoxon signed ranks test.

*p*-value†, comparison between pre and post-DBS in the older group by paired Students' *t*-test or Wilcoxon signed ranks test.

*p*-value‡, comparison of pre-DBS data between the younger and older groups by unpaired Student's *t*-test or Mann-Whitney U test.

# Deep brain stimulation in Parkinson's disease

S. J. Groiss, L. Wojtecki, M. Südmeyer and A. Schnitzler

*Ther Adv Neurol Disord*  
(2009) 2(6) 379–391  
DOI: 10.1177/  
1756285609339382

## Inclusion

1. clinically idiopathic PD
2. significant improvement with regard to dopaminergic medication (>30%)
3. refractory motor fluctuations or tremor
4. only minor symptoms during ON-state

## Exclusion (relative)

1. biological age over 75 years
2. severe/malignant comorbidity with considerably reduced life-expectancy
3. chronic immunosuppression
4. distinct brain atrophy
5. severe psychiatric disorder (cognitive deficits/dementia, frontal-dysexecutive syndrome, manifest psychosis, depression, substance abuse, personality disorder)

# An update on best practice of deep brain stimulation in Parkinson's disease

Christian J. Hartmann , Sabine Fliegen, Stefan J. Groiss, Lars Wojtecki and Alfons Schnitzler

*Ther Adv Neurol Disord*

2019, Vol. 12: 1–20

DOI: 10.1177/  
1756286419838096

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- a) presence of motor fluctuations including levodopa-sensitive off symptoms or treatment-induced dyskinesia
- b) tremor, which cannot be satisfactorily treated with medication
- c) a levodopa-induced reduction of motor symptoms by >33% of the Unified Parkinson Disease Rating Scale (UPDRS), where tremor may be disregarded from the calculation as it may be refractory to levodopa treatment while still responding well to DBS
- d) exclusion of dementia, relevant psychiatric or somatic comorbidity, or general contraindication to undergo neurosurgical interventions.
- e) Even more restrictive inclusion criteria are recommended for patients not older than 60 years and the presence of motor fluctuations for not longer than 3 years

# PD Genetics and Deep Brain Stimulation

- Although DBS shows good outcome initially, long-term outcomes are not well-known in many genotypes and selection bias should be considered
- In terms of motor fluctuation, DBS may demonstrate good long-term outcomes, but other symptoms (axial symptoms, cognition or psychiatric symptoms) can be more problematic in long-term follow-up (SNCA, GBA)
- Especially in GBA-related PD, STN DBS should be decided carefully due to the 'cognitive frailty' and it seems reasonable to consider the 'cognitively safer' GPi-DBS instead of STN-DBS, but still controversial

# Cognitive and Psychiatric Symptoms

- Dementia is absolute contraindication for deep brain stimulation, but no consensus about mild cognitive impairment
- DBS is usually not considered in unstable psychiatric conditions until the symptoms have been managed adequately, although ongoing severe depression with suicidal ideation should be considered an absolute contraindication
- Limited evidence suggests that GPi may be safer than STN for patients with cognitive, or behavioral issues
- Caregiver is important, especially in patients with cognitive or behavioral problems
- Also, there can be other options, especially MRgFUS?

Munhoz RP et al, 2016

# Adaptive DBS & Cognitive/Psychiatric Complications

- No evidence yet, but...

# DBS Indications in PD, can be widened?

- Basic indication
  - Motor fluctuation responsive to levodopa or/and dyskinesia
  - Medication-refractory tremor
- Contraindication
  - Dementia/Severe psychiatric symptoms
  - Poor general conditions and severe comorbidities
- Should also consider
  - Age
  - Genetic backgrounds
  - Mild cognitive decline, psychiatric comorbidities

# Targets for Deep Brain Stimulation

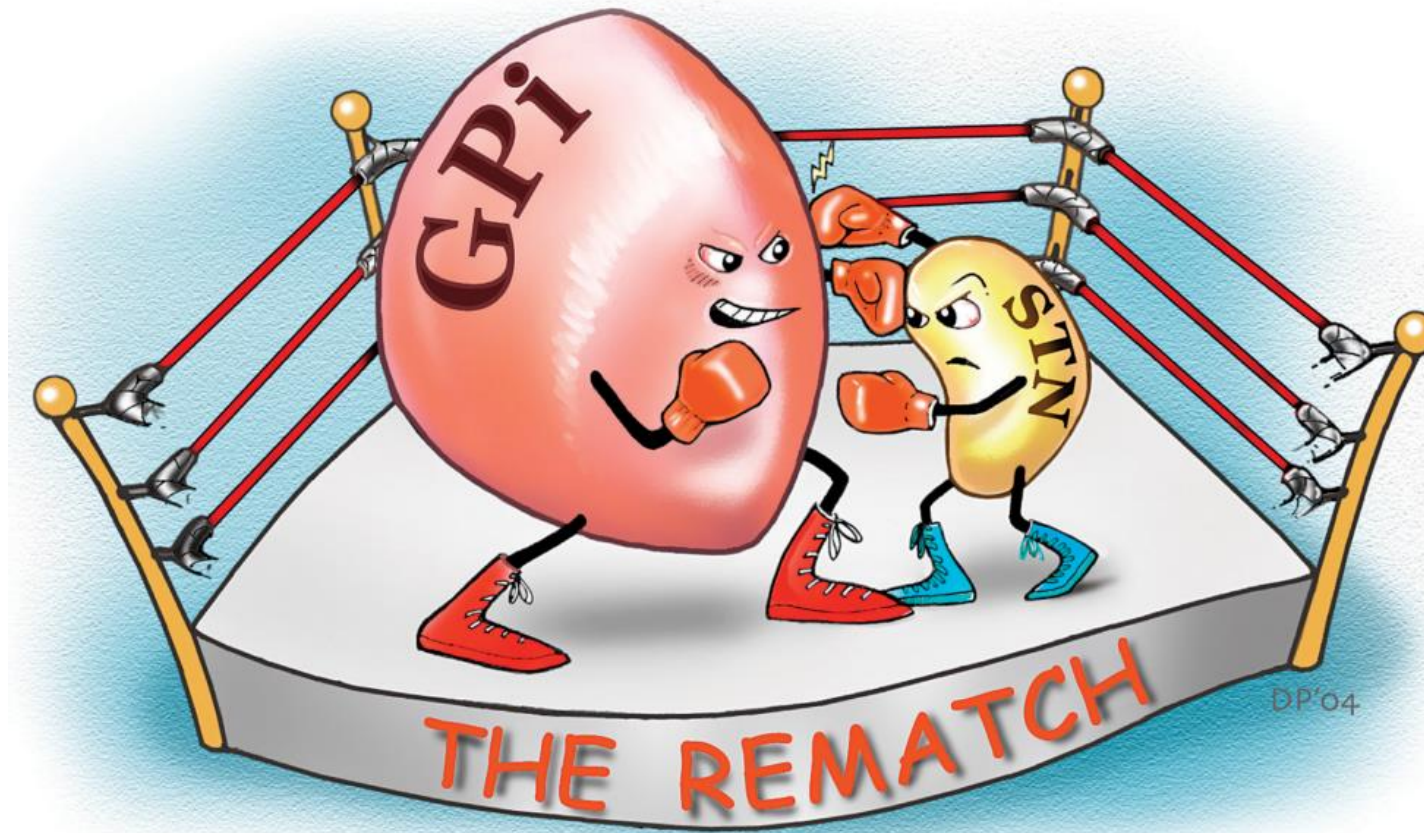
Gpi stimulation	STN stimulation
Direct effect on dyskinesia	Easy to Approach Decrease medication
Gait and posture problem	Depression/ICD? Cognition

- **GPI DBS, safer but less reduction of medication**
  - Elderly PD patients
  - Severe dyskinesia
  - Patients with psychiatric problems
- **STN DBS, more reduction of medication**
  - Younger PD patients
  - Normal cognition, psychiatric profile

Liu Y et al. 2015

From: **Subthalamic Nucleus vs Globus Pallidus Interna Deep Brain Stimulation, the Rematch: Will Pallidal Deep Brain Stimulation Make a Triumphant Return?**

Arch Neurol. 2005;62(4):533-536. doi:10.1001/archneur.62.4.533



# Adaptive DBS can kill GPi DBS?

A



Stim increased because feeling "OFF"

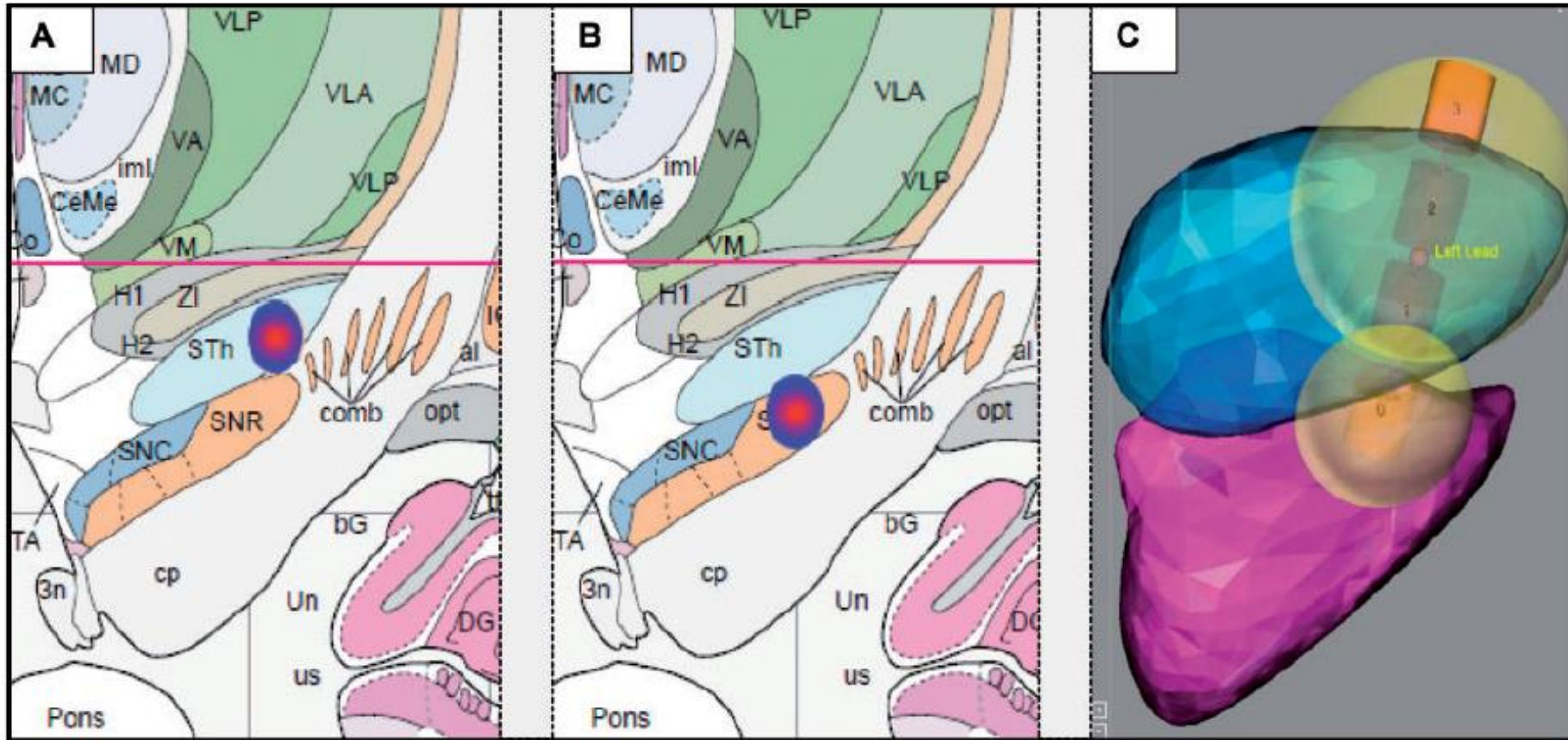
ON/OFF fluctuations  
Related to stim + med adjustment

Stim decreased because feeling dyskinetic

# Target symptoms of DBS

- Classically levodopa-responsive symptoms in Parkinson's disease except tremor
- Motor fluctuation and some non-motor fluctuation
- However, with disease progression, PD presents with more and more axial symptoms
  - Advanced program options such as lower frequency stimulation
  - But also new targets: pallidothalamic tract, ZI, substantia nigra, etc.

# Stimulating Multiple Targets



Weiss D et al. 2013

# An update on best practice of deep brain stimulation in Parkinson's disease

Christian J. Hartmann , Sabine Fliegen, Stefan J. Groiss, Lars Wojtecki and Alfons Schnitzler

*Ther Adv Neurol Disord*

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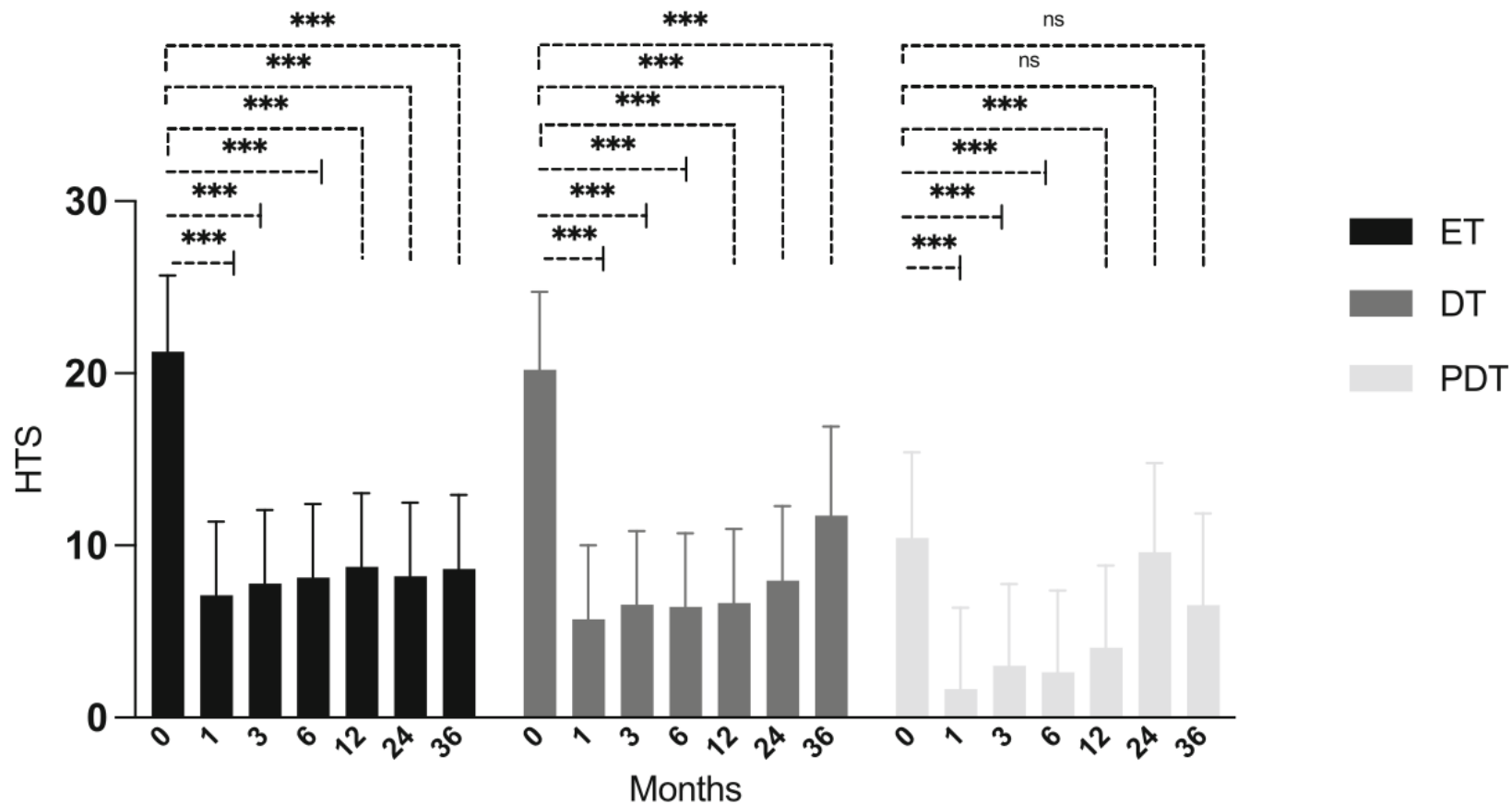
- a) presence of motor fluctuations including levodopa-sensitive off symptoms or treatment-induced dyskinesia
- b) tremor, which cannot be satisfactorily treated with medication**
- c) a levodopa-induced reduction of motor symptoms by >33% of the Unified Parkinson Disease Rating Scale (UPDRS), where tremor may be disregarded from the calculation as it may be refractory to levodopa treatment while still responding well to DBS
- d) exclusion of dementia, relevant psychiatric or somatic comorbidity, or general contraindication to undergo neurosurgical interventions.
- e) Even more restrictive inclusion criteria are recommended for patients not older than 60 years and the presence of motor fluctuations for not longer than 3 years

# Medication-refractory PD tremor

- Medication-refractory tremor was reported in 30-40% in PD patients
- Tremor-specific medications, such as anticholinergics, can be associated with cognitive decline, especially in elderly patients
- We also have options: Lesioning including MRgFUS and DBS
- If we choose DBS, consider targets: Vim vs. STN DBS vs. PSA

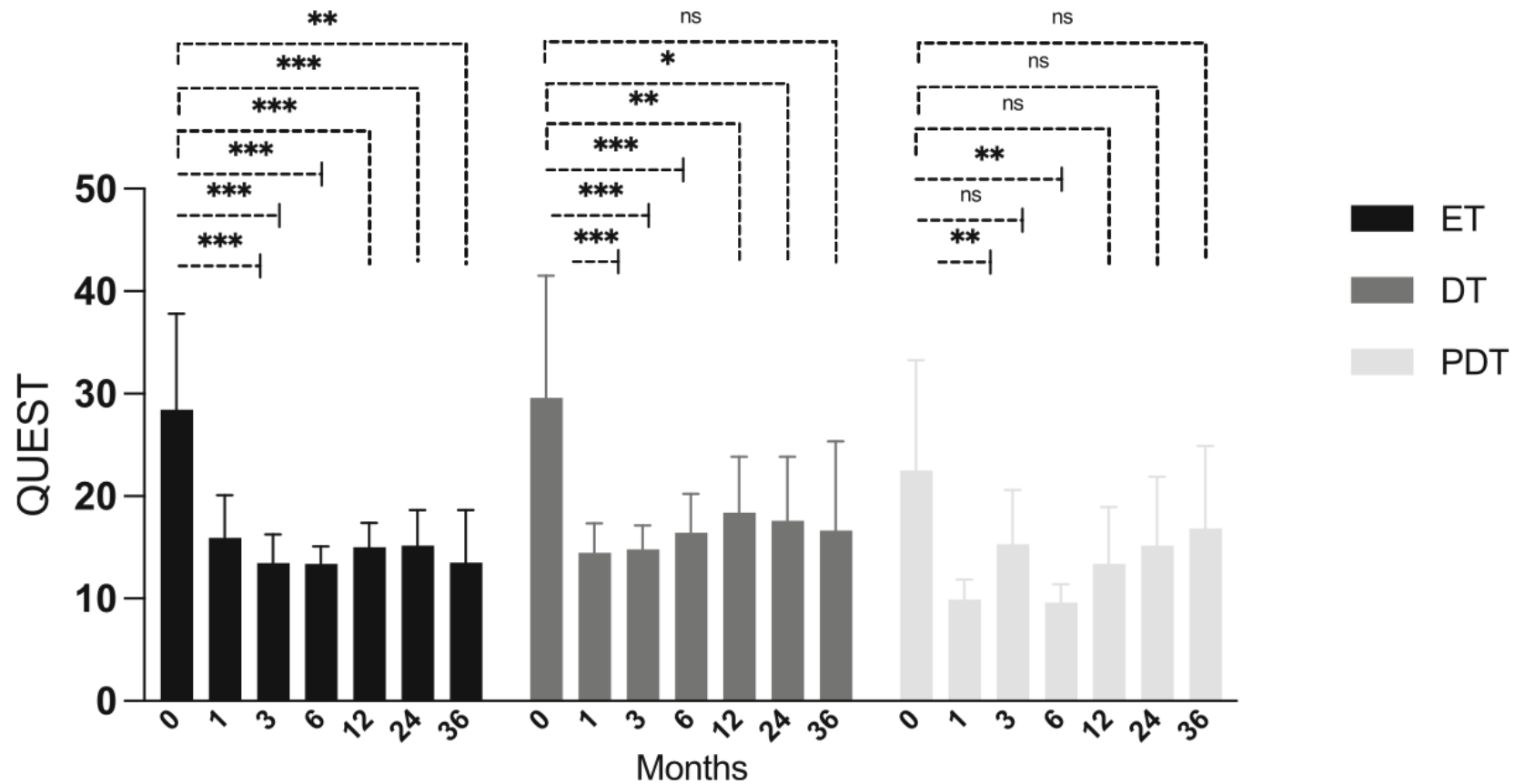
Zach H et al. 2020

## Hand Tremor Score



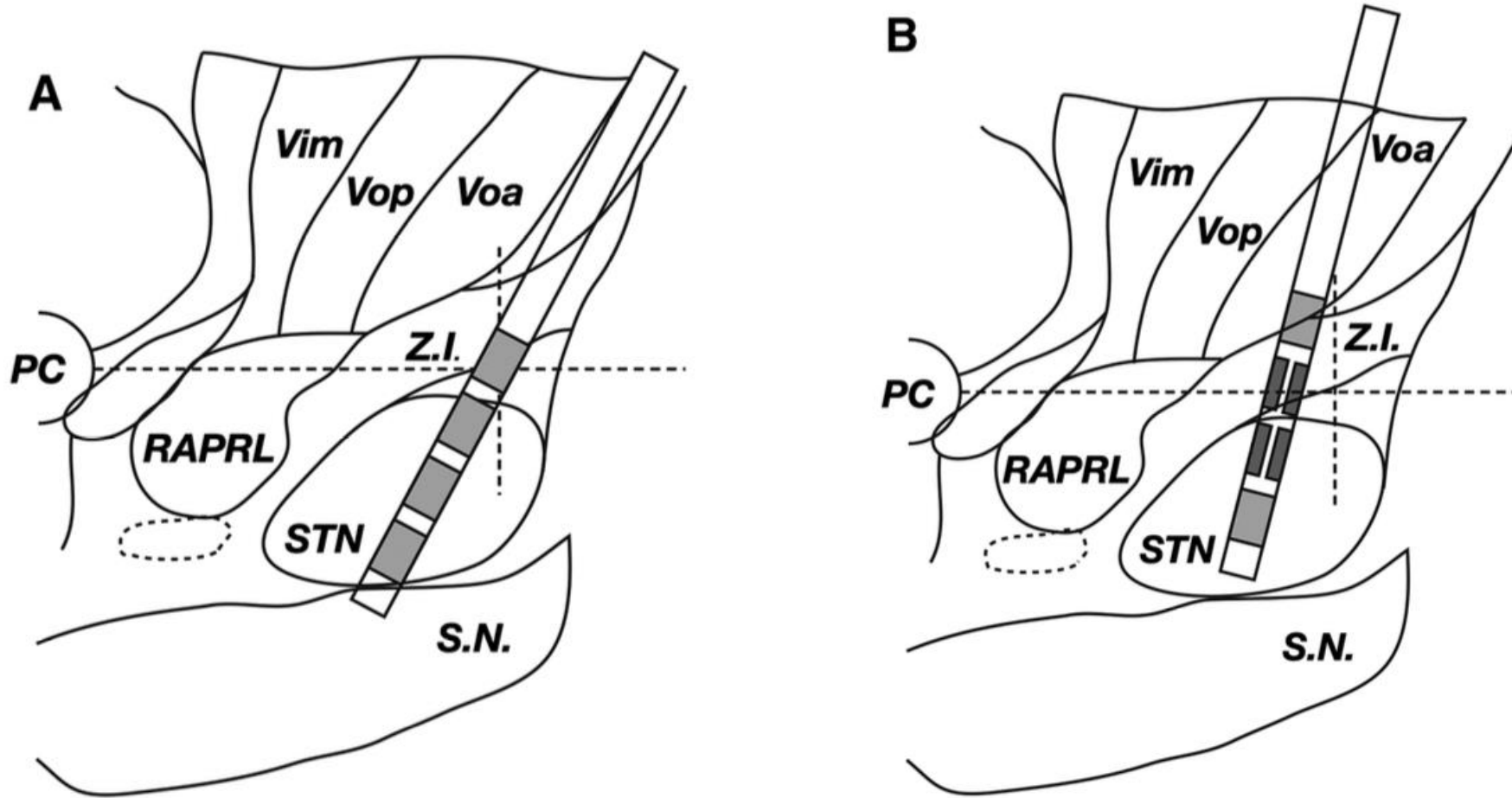
**FIG. 2.** Longitudinal outcomes in CRST hand tremor score after MRgFUS (magnetic resonance image-guided focused ultrasound) thalamotomy between tremor subtypes. Estimated marginal means  $\pm$  standard error. Analysis adjusted for age and disease duration. \*\*\* $P < 0.001$ , \*\* $P < 0.01$ , and \* $P < 0.05$ .

## Quality of Life



**FIG. 3.** Longitudinal outcomes for quality of life as measured using QUEST (Quality of Life in Essential Tremor Questionnaire) after MRgFUS (magnetic resonance image-guided focused ultrasound) thalamotomy between tremor subtypes. Estimated marginal means  $\pm$  standard error. \*\*\* $P < 0.001$ , \*\* $P < 0.01$ , and \* $P < 0.05$ .

# Change in Surgical Strategy?



Masuda H et al. 2021

# Take Home Message

## Neurologists' Prospective

### Indication

**More DBS candidates**

- Age
- Genetic
- Phenotype
- Target

### Programming

- Image-guided programming
- AI based programming
- Local field potential

**More programming options for maximal benefits and axial symptoms with disease progression**

## Neurosurgeons' Prospective

### Surgery

- Robot surgery
- Asleep or awake surgery
- Lead depth

**Personalized surgery based on patients' symptoms and risk**

**Troubleshooting**