5th Neuromodulation School for Movement Disorders

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International Parkinson and Movement Disorder Society Pan American Section

Fundamentals of DBS programming: Initial Programming and Optimization

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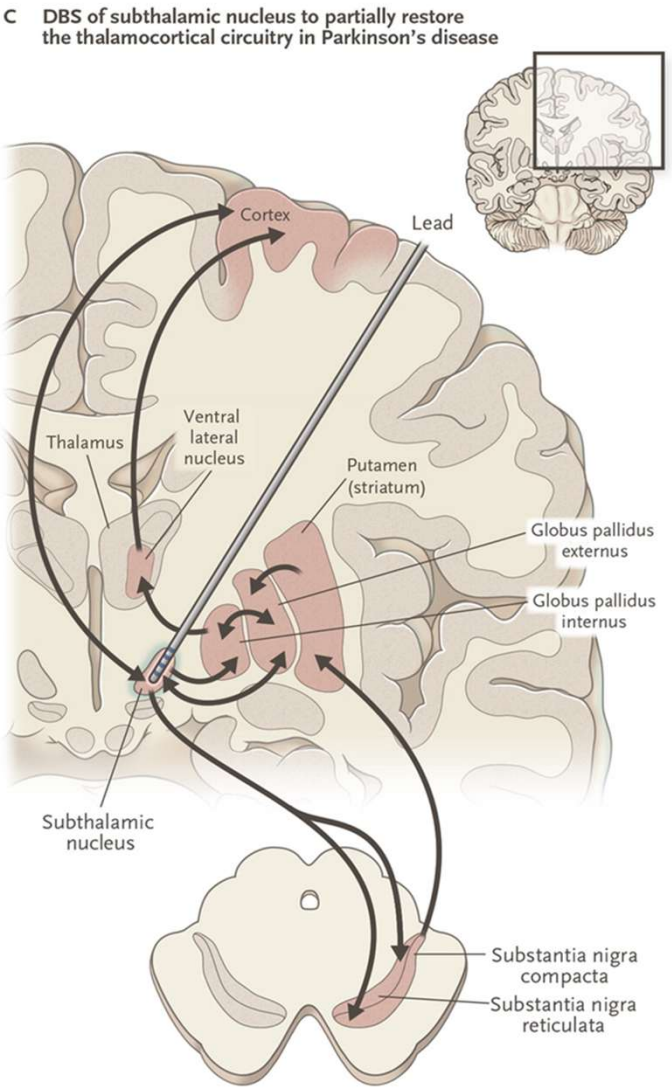
Mount Sinai

DBS programming = field shaping

BASIC PRINCIPLES

Goals of DBS programming

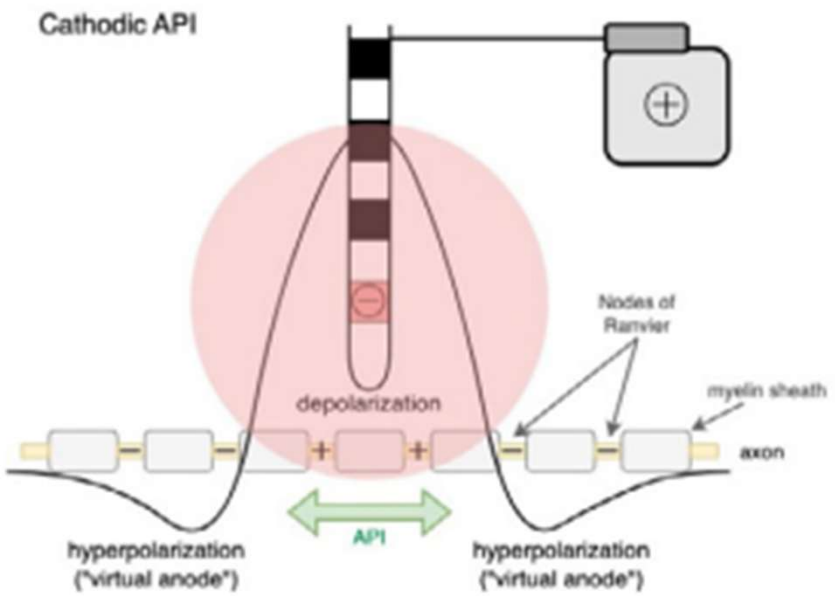
- Improve motor symptoms of movement disorders by engaging the appropriate networks
  - Achieved by creating a field of stimulation that affects downstream signaling
- Limit side effects of stimulation
  - Must take surrounding structures and pathways into consideration



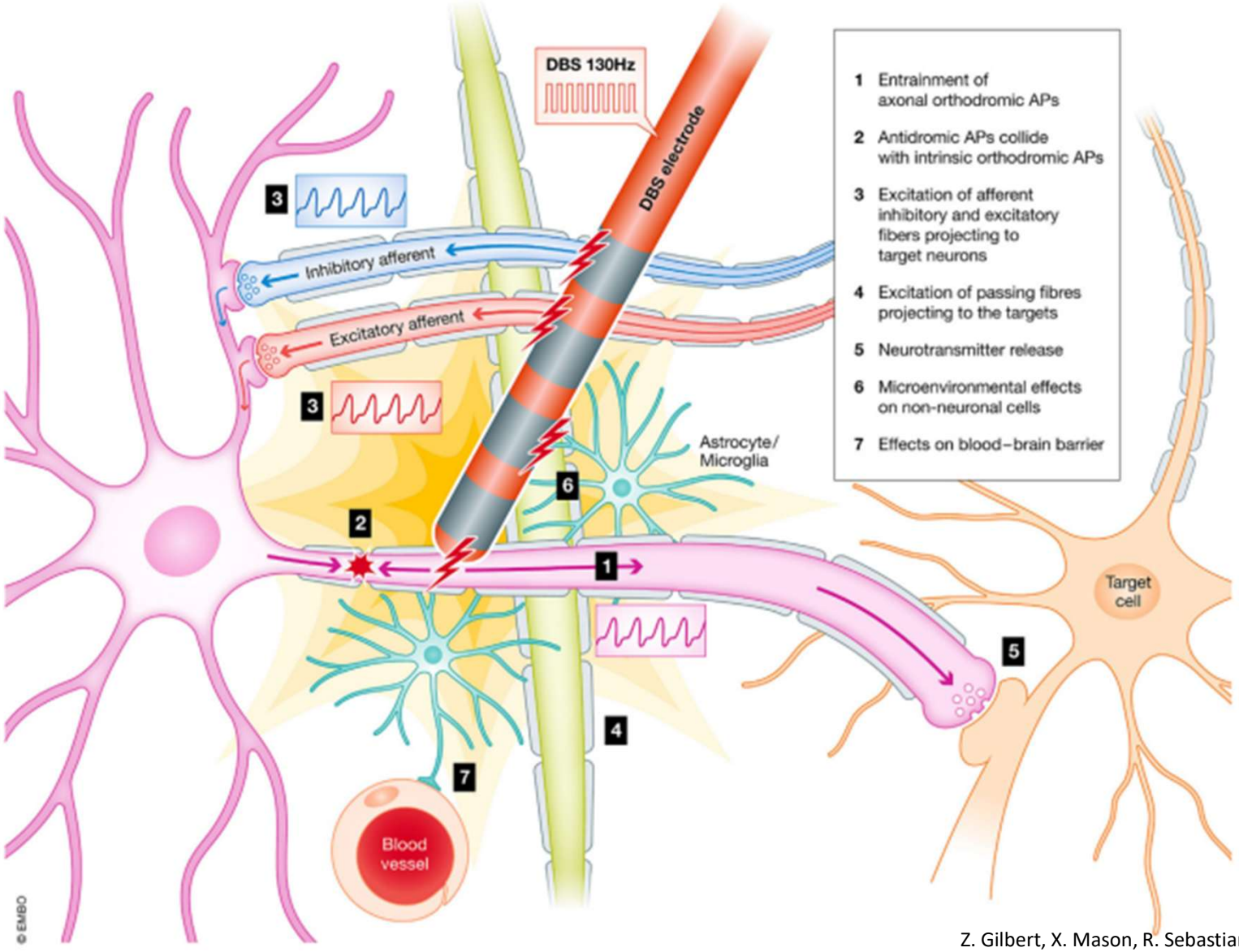
Okun MS. N Engl J Med 2014;371:1369-1373.

DBS generally delivers cathodic stimulation

- “Cathodic stimulation” : IPG acts as the anode (+) and the active electrode contact as the cathode (-) [in monopolar stimulation]
- Current (negative charges) flows from the anode to the cathode
- Neuronal elements within the volume of tissue activation may depolarize with action potential initiation



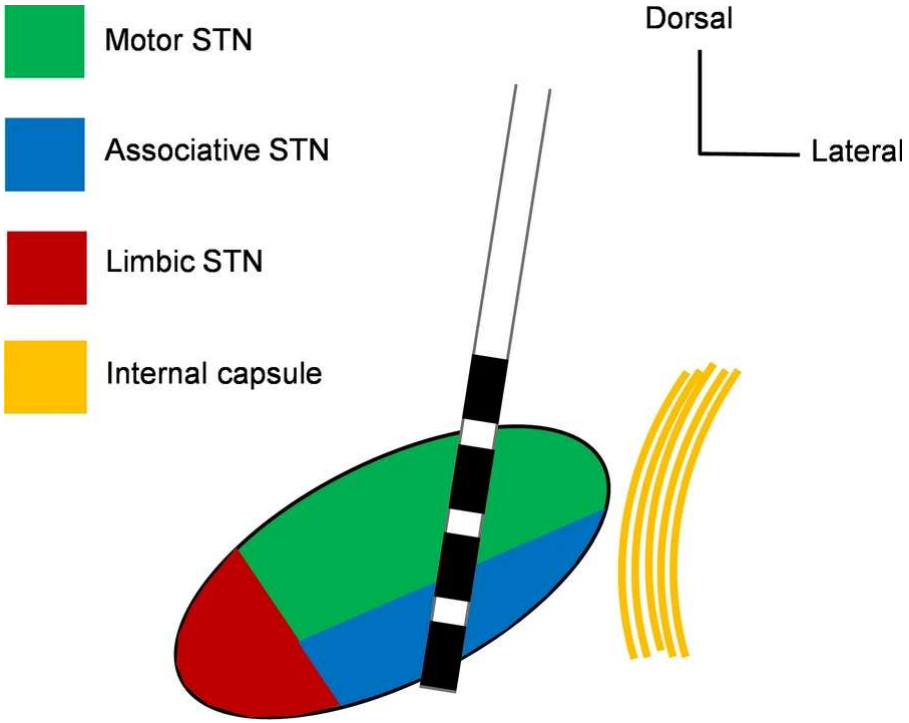
Z. Gilbert, X. Mason, R. Sebastian et al. Clinical Neurophysiology 152 (2023) 93–111

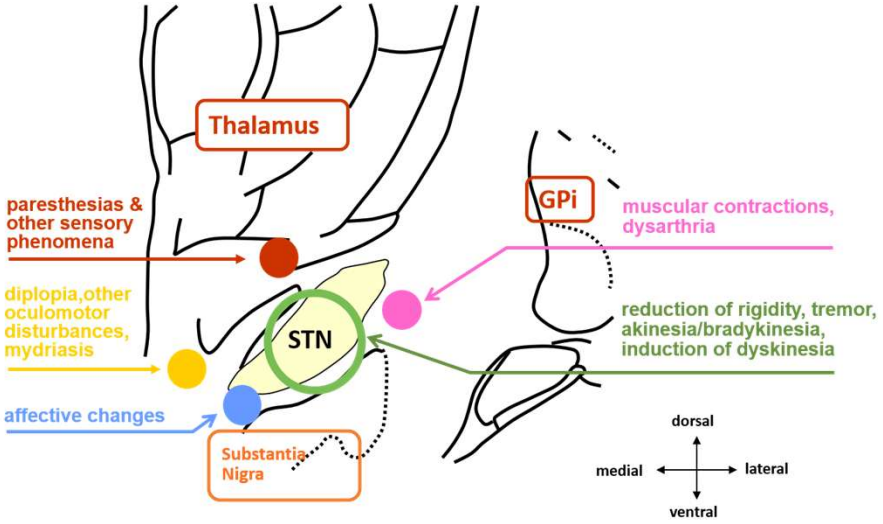


Many neural elements may be affected withing the volume of tissue activation

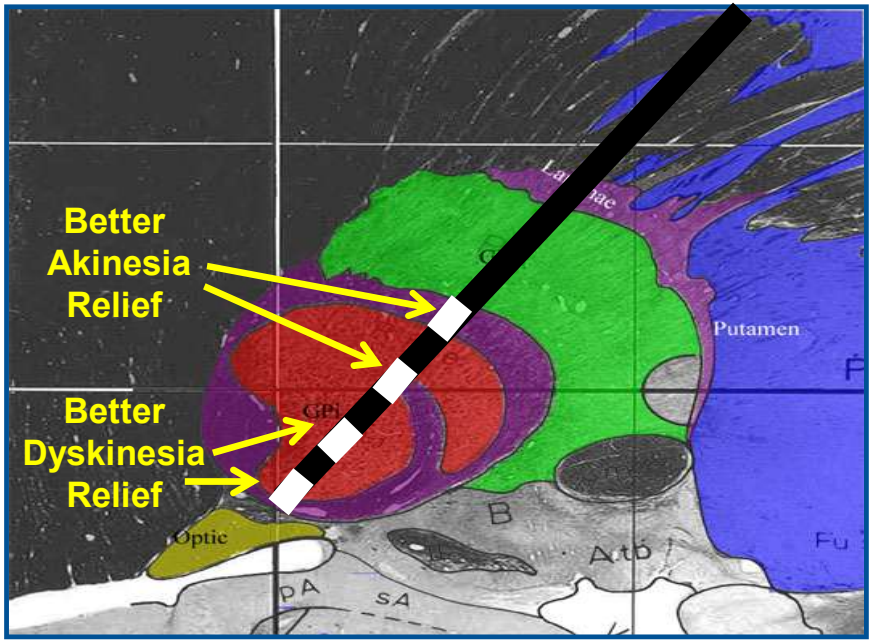
Z. Gilbert, X. Mason, R. Sebastian et al. Clinical Neurophysiology 152 (2023) 93–111

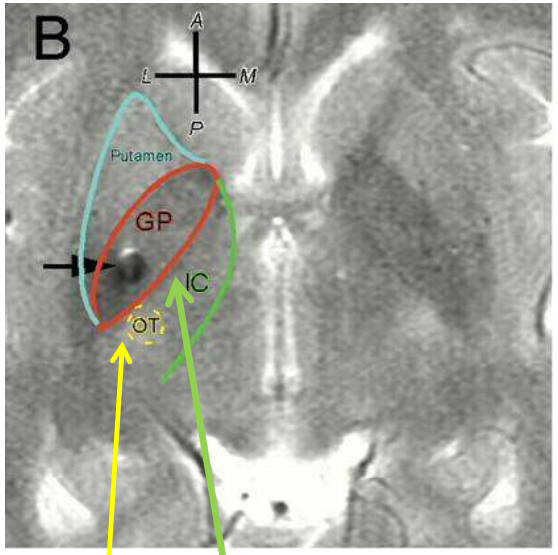
STN stimulation





Region of interest: Posteroventral GPi





Tonic contractions
Dysarthria
(posteromedial)

Visual
phenomena

Thalamic (Vim) Stimulation

- Paresthesias:

Posterior (Vc)

- Dysarthria:

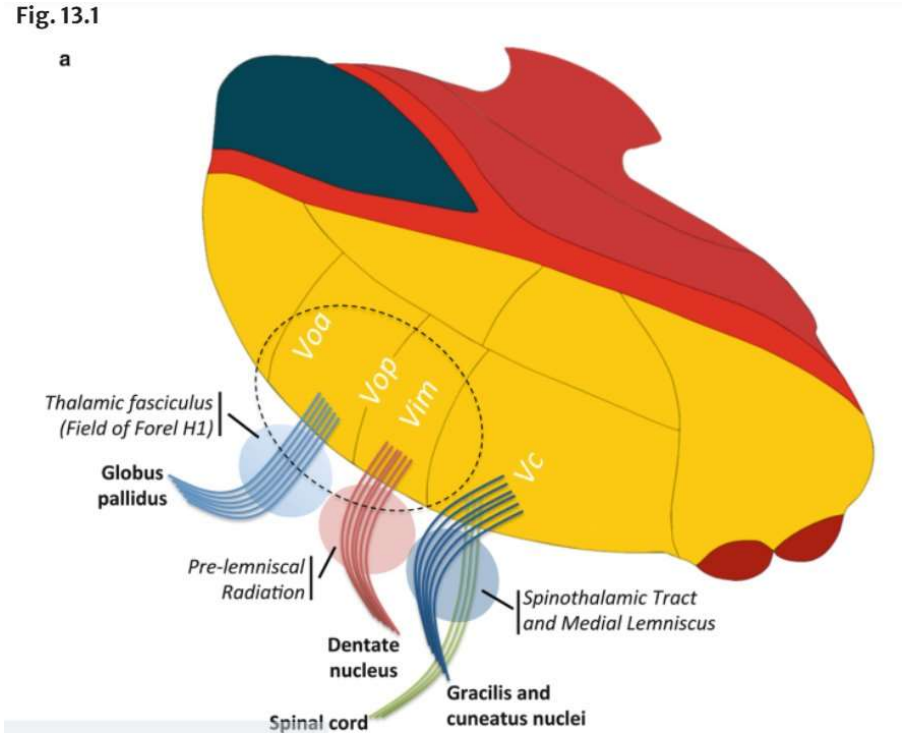
Lateral or posteromedial

- Tonic contractions:

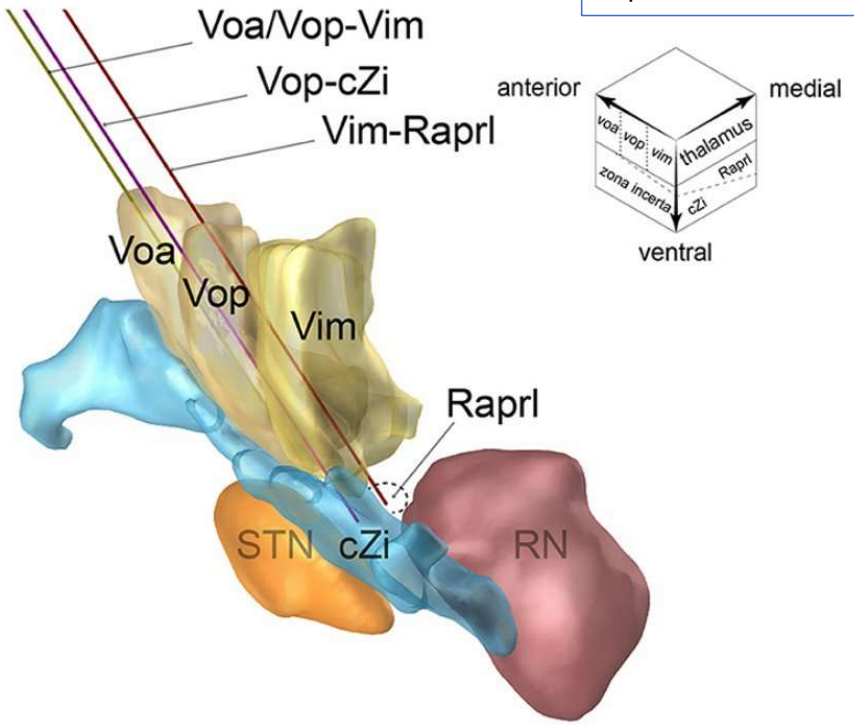
Lateral

- No effect

Superior or anterior



Fasano, A., Coenen, V.A. (2020). Tremor. In: Temel, Y., Leentjens, A., de Bie, R., Chabardes, S., Fasano, A. (eds) Fundamentals and Clinics of Deep Brain Stimulation. Springer, Cham. https://doi.org/10.1007/978-3-030-36346-8_13



https://www.frontiersin.org/journals/human-neuroscience/articles/10.3389/fnhum.2022.790942/full

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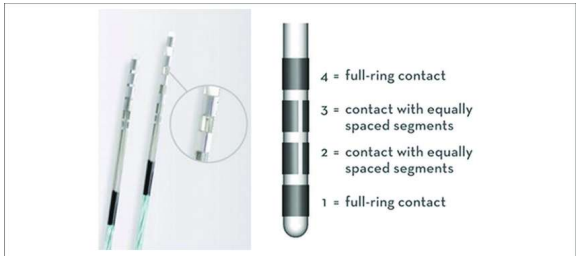
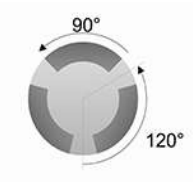
INITIAL PROGRAMMING

Traditional approach: monopolar review

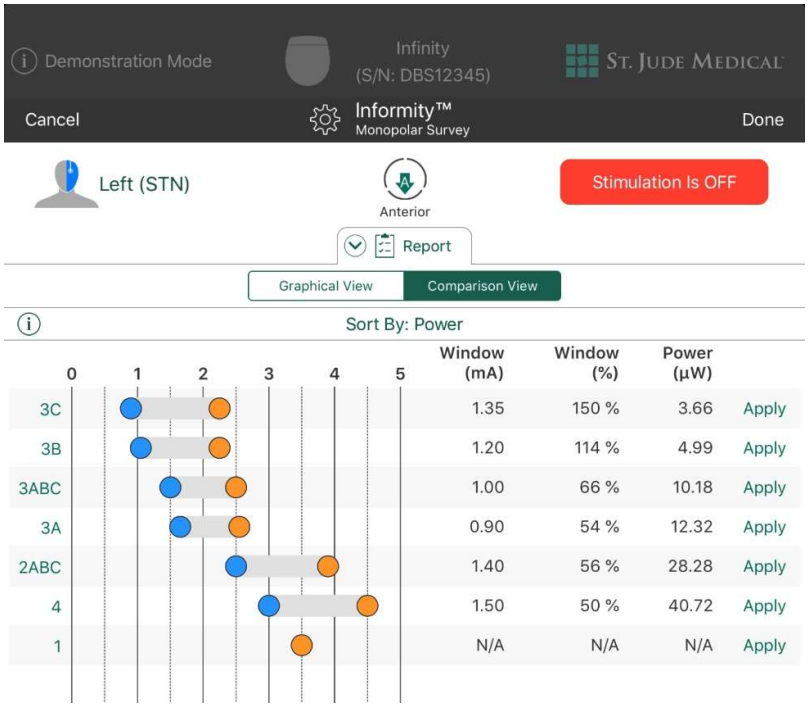
- Performed at first visit or when troubleshooting
- For PD, it is most advisable to do this OFF meds
- Intent is to find <u>optimal contact</u> for stimulation
  - Set a constant Freq (125-130Hz) and PW (60usec – 90usec)
  - Titrate amplitude (e.g., 0.5mA for ring, 0.25mA for segments)
  - Assess "therapeutic window" of each contact individually:
    - Onset of therapeutic benefit
    - Onset of stimulation-induced side effects
- Get "in the ballpark"

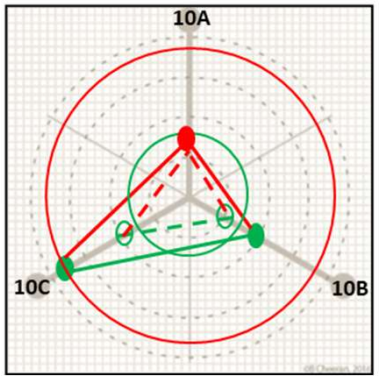




Monopolar review: traditional documentation

Polarity	Amp (V)	PW (usec)	Freq (Hz)	Notes
C+1-		60	130	
	0.5			No change
	1.0			No change
	1.5			Slight improvement in BK
	2.0			BK resolves. Slight impr in tremor
	2.5			Further reduction in tremor
	3.0			Tremor resolves
	3.5			No AEs
	4.0			Face pulling
	3.8			Side effects resolve
	4.0			Recurrent face pulling



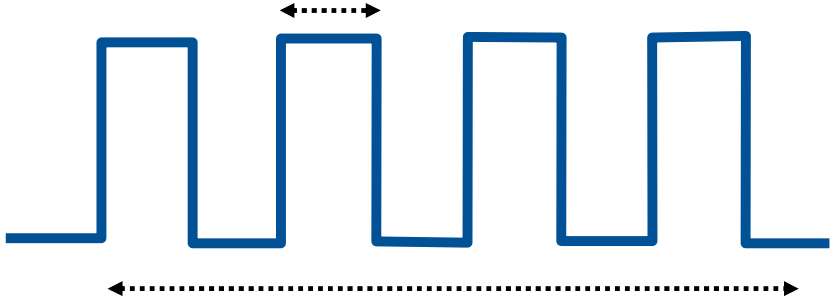


What is the therapeutic window?

Adjusting electrical parameters determines the size/intensity of the field

Pulse Width
(μsec)
duration of each stimulus

Secondary parameter contributing to total charge density
↑ PW increases chance of depolarization → activate additional elements
↓ PW widens therapeutic window



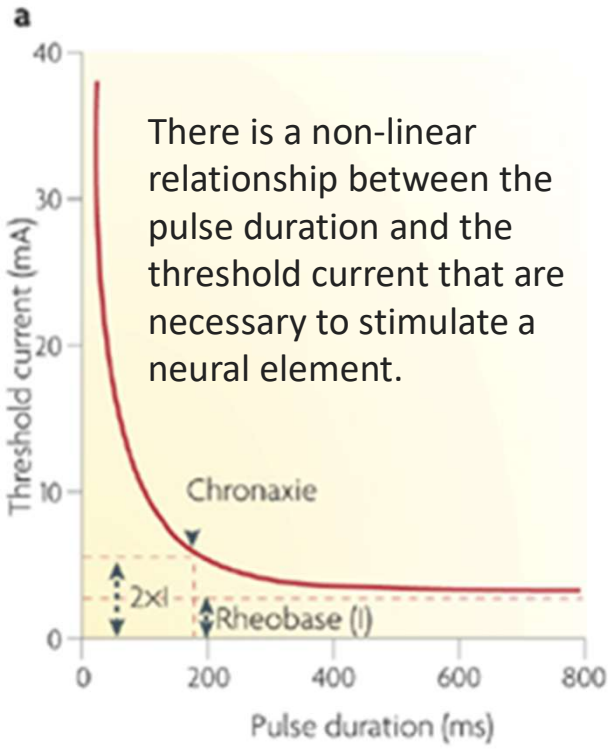
Amplitude
(Volts or mA)
intensity of stimulation

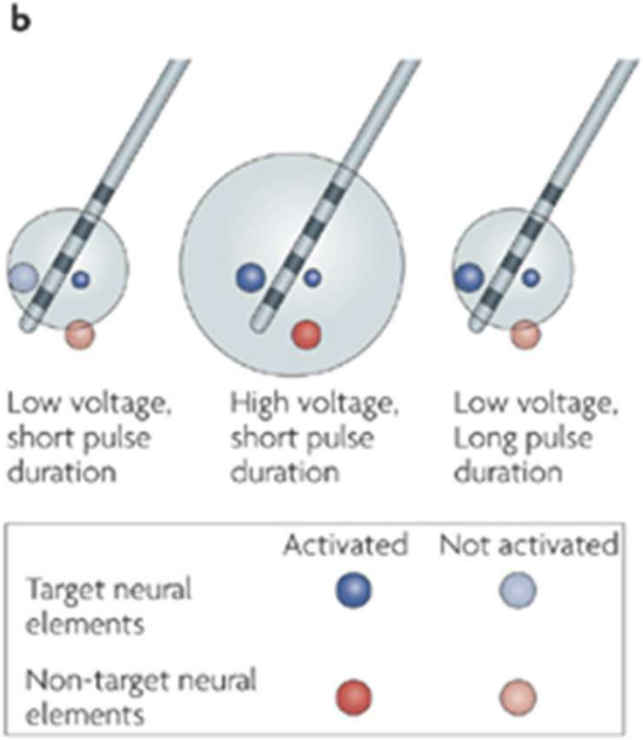
The main parameter used to control the intensity of stimulation
↑ amplitude → ↑field of stimulation

Rate
(Hertz)
number of pulses per second

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

Relationship between PW and Amp





IMPLICATIONS:

- Increasing PW will decrease the amplitude required for initiation of an action potential
- But if you increase PW too far there are diminishing returns
- Large caliber, highly myelinated axons (ie IC) have short chronaxie (meaning you are more likely to recruit them as you increase PW)

Rheobase: The lowest electrical strength needed to cause a reaction when applied for a very long time.
Chronaxie is the minimum time (PW) needed to trigger a nerve or muscle using an electrical current that is twice as strong as the rheobase. (how easily tissue responds to electricity)

Kringelbach ML, et al. Translational principles of deep brain stimulation. Nature Reviews Neuroscience. 2007.

Adjustment strategy for the early programming sessions

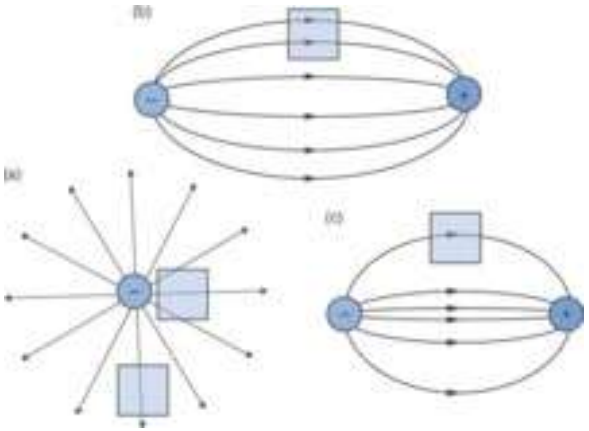
- Amplitudes at end of 1st programming are often 1.5-2.5V/mA
  - May be lower if you are programming using a single segment

- If you have done good work in the 1st programming session you generally should not have to change polarity
  - Exception: managing side effects

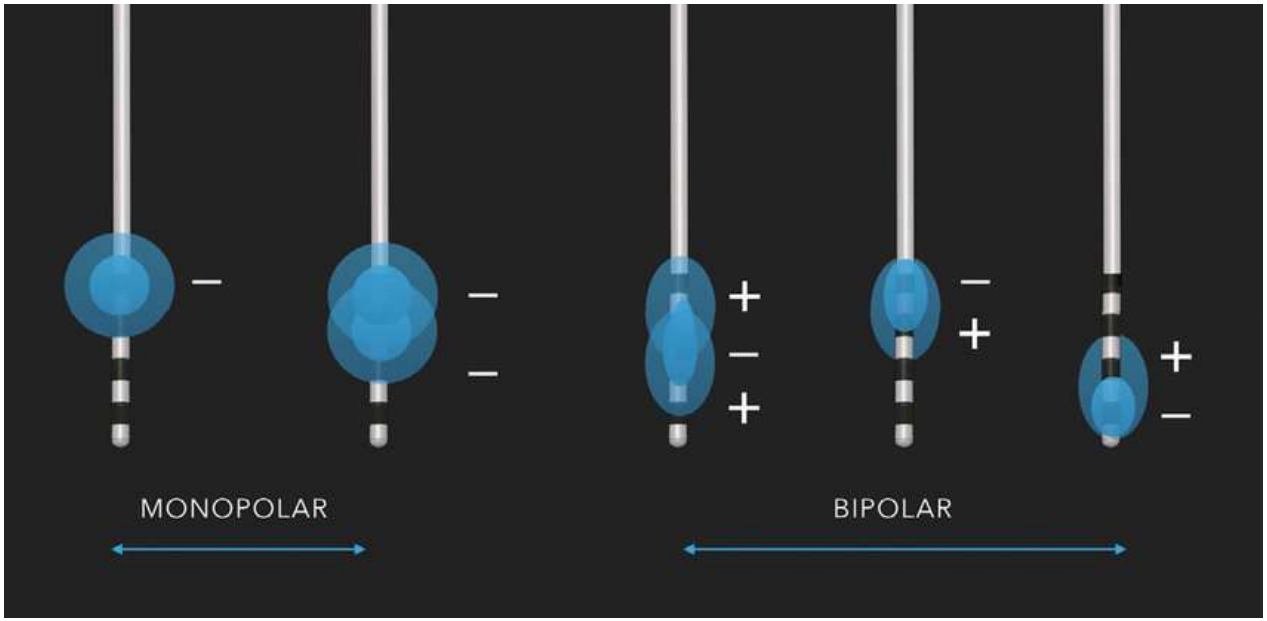
- Subsequent sessions are used to “fine tune” the stimulation –mostly titrating amplitude
  - Rule of thumb is 0.2-0.4mA increase per session
  - Other specific changes according to effects, side effects
  - Eg Freq or PW adjustments

FIELD SHAPING

Focus the field of stimulation – monopolar vs. bipolar configurations



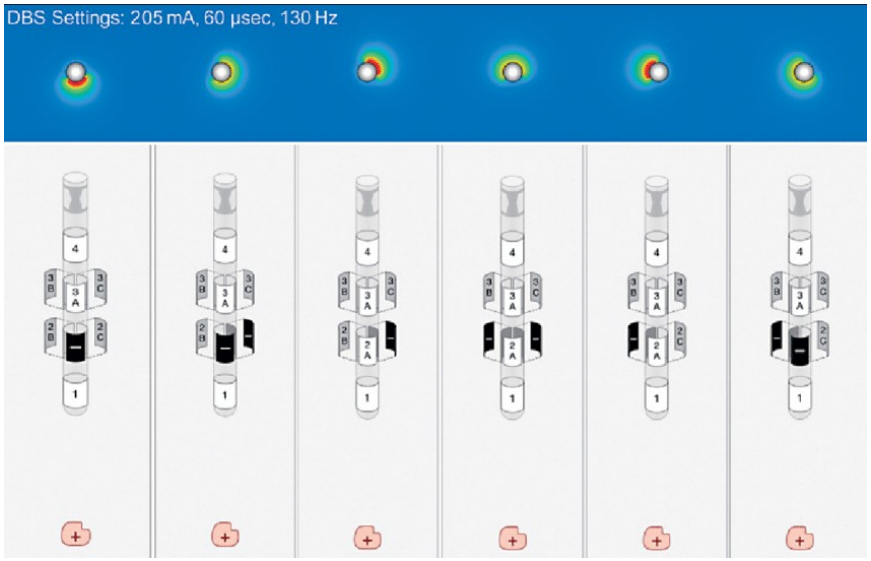
Montgomery, E.B. (2010) 'Principles of neurostimulation', in Marks, Jr, W.J. (ed.) *Deep Brain Stimulation Management:*. Cambridge: Cambridge University Press, .



Westen, M et al. (2020). Optimizing Deep Brain Stimulation Parameters in Obsessive–Compulsive Disorder. Neuromodulation: Technology at the Neural Interface. 24. 10.1111/ner.13243.

Current steering with directional leads

- Activation of cathode steers the electric field towards the target of interest
- Can deactivate a segment that may be inducing adverse effects
- Single segment activation may improve energy efficiency
- Especially useful for stimulation of small nuclei
- ?suboptimally placed electrodes

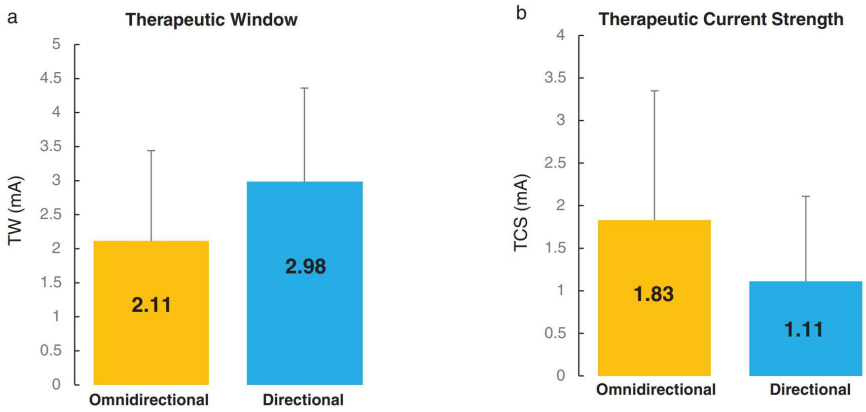


Reker P, Dembek TA, Becker J, Visser-Vandewalle V, Timmermann L. Directional deep brain stimulation: A case of avoiding dysarthria with bipolar directional current steering. Parkinsonism Relat Disord. 2016 Oct;31:156-158.

Directional Deep Brain Stimulation for Parkinson's Disease: Results of an International Crossover Study With Randomized, Double-Blind Primary Endpoint.

Schnitzler A et al. Neuromodulation. 2021 May 27. doi: 10.1111/ner.13407.

- N=234
- All subjects omnidirectional stim x 3 mos → directional stim x 3 mos
- Primary endpoint = difference in therapeutic window at 3 mos between omni- and directional stim



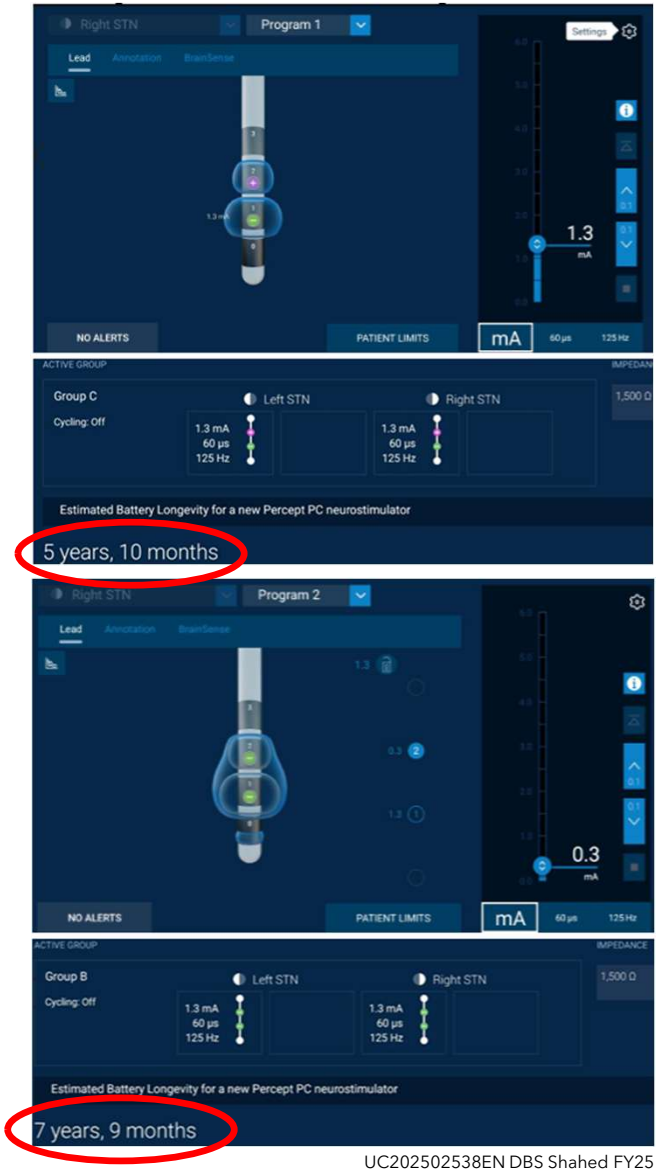
Bipolar vs OptiStim in Percept®

- TEED = I^2 x R x PW x F
  - TEED %improvement = $TEED_{mono}$ / $TEED_{bip}$

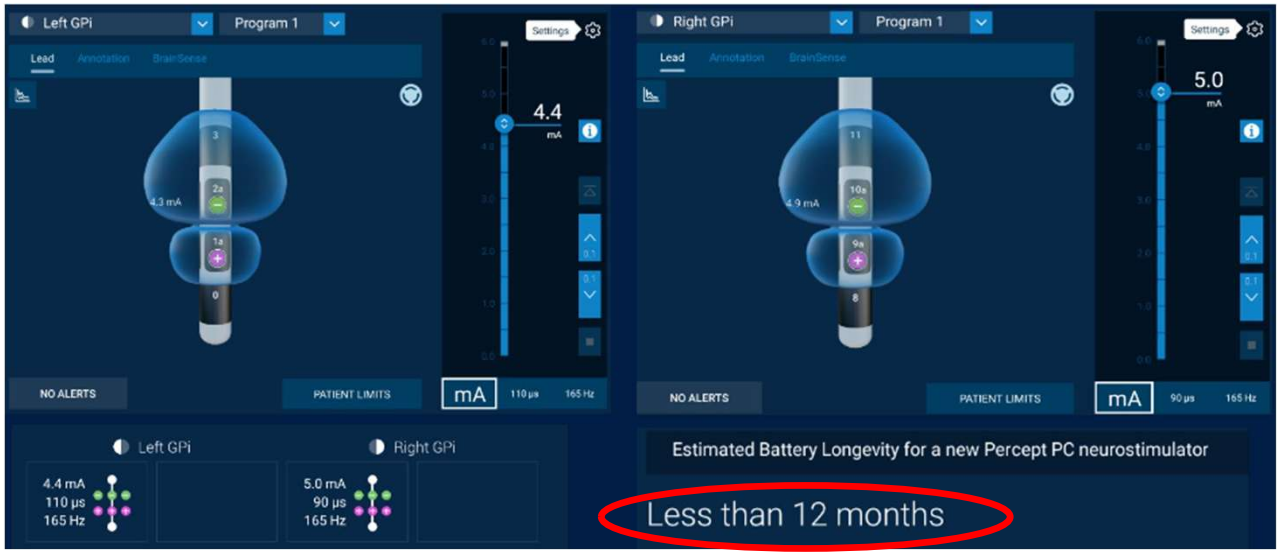
- In *bipolar configuration*, impedance doubles
  - $TEED_{bip}$ = 2 x R_{mono}
  - If R_{mono} = 1500Ω, then R_{bip} = 3000Ω
- In *OptiStim (monopolar)*, the current is additive

- In this example
  - $TEED_{bip}$ = 1.3^2 x 60 x 125 x 3000 = 38,025,000
  - $TEED_{mono}$ = (0.3^2+1.3^2) x 60 x 125 x 1500 = 20,025,000

- TEED %improvement = 53% (minus some for added current needed for onboard processing)



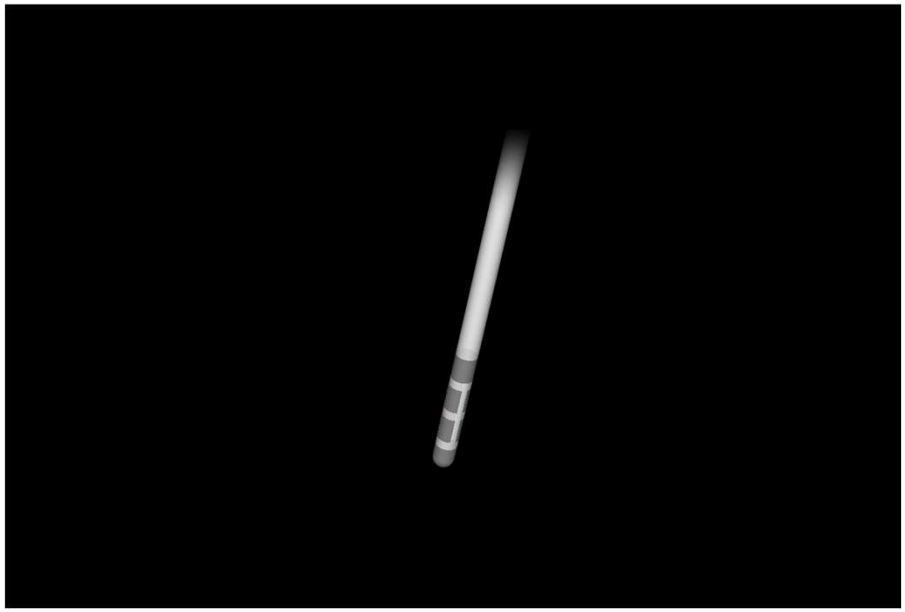
Actual bipolar parameters

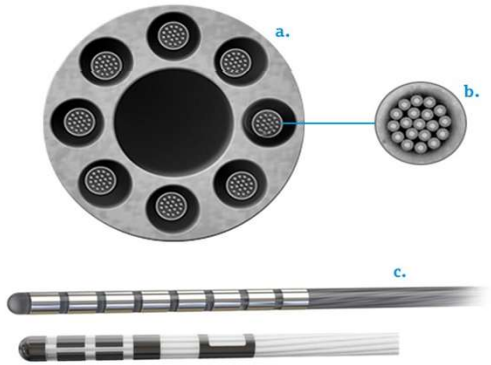


Proposed OptiStim parameters

Complex field shaping by MICC

- Eight linear contacts or 1-3-3-1 directional lead design
- Dedicated power source for each contact
- Constant current generator





http://www.bostonscientific.com/en-EU/products/deep-brain-stimulation-systems/Vercise-DBS.html

FOLLOW-UP PROGRAMMING

Follow-up DBS programming visits

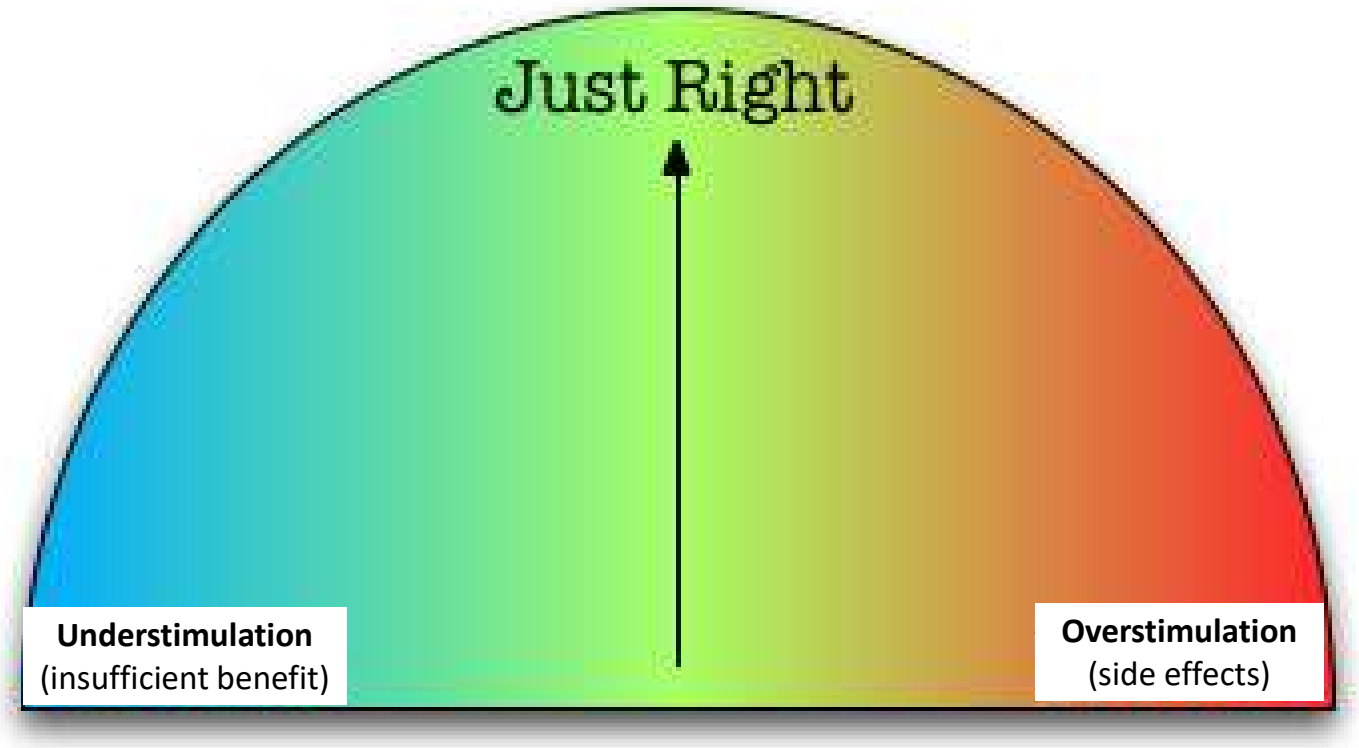
- Look at what was done at last programming session
  - Programming + medication changes
  - Was desired effect achieved?

- Assess interim changes/new symptoms
  - Is there adequate control of disease related symptoms/features?
- Decide if there is a need for DBS adjustment
  - Is there a stimulation-related issue?
  - Is there a medication management issue?
  - Is there disease progression?

- Formulate management strategy

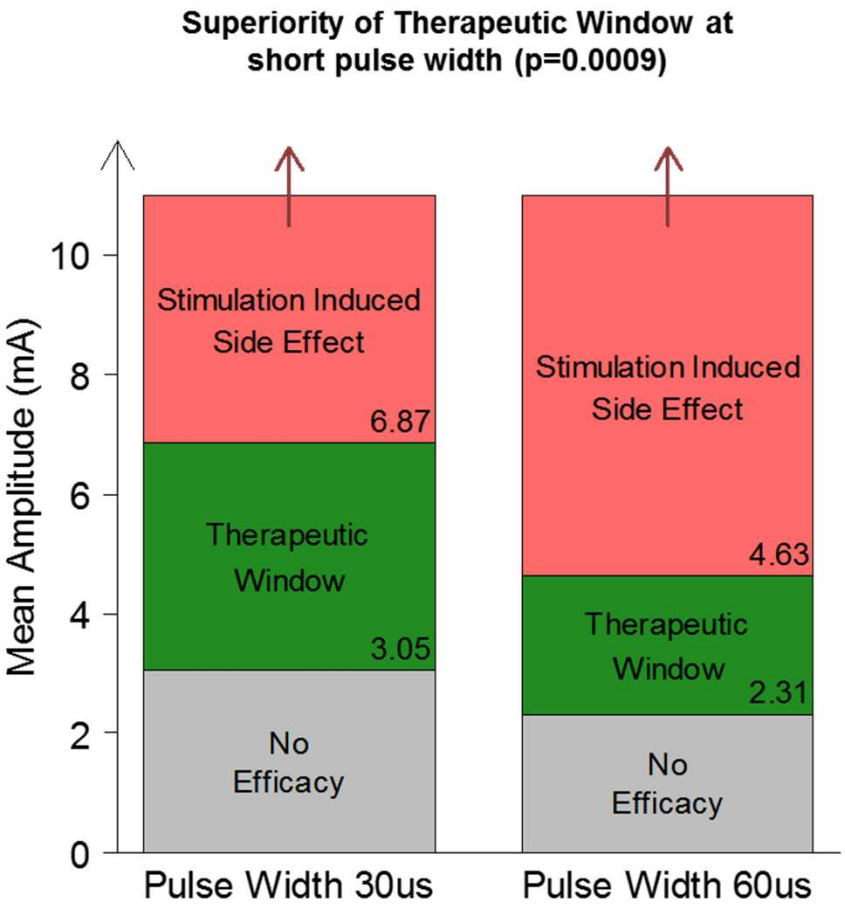
- Check hardware integrity

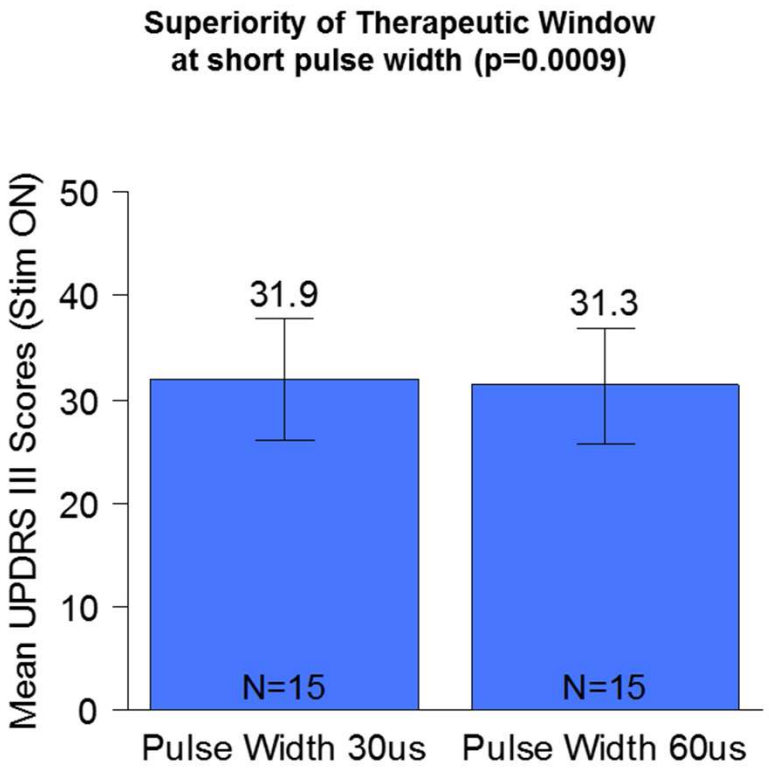
Doing well
(or need to change other things)



DBS Temperature Monitor

Shortened PW: CUSTOM Clinical Trial

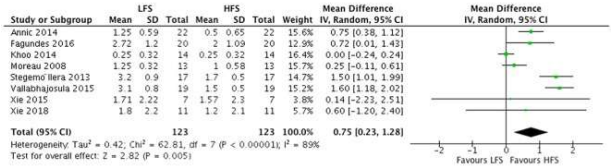




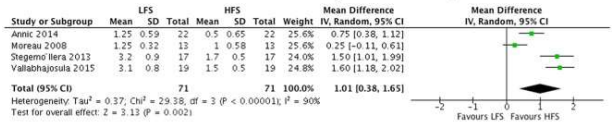
Mov Disord. 2018 Jan; 33(1): 165–169. / Published online 2017 Nov 22. doi: 10.1002/mds.27238

Low frequency in STN

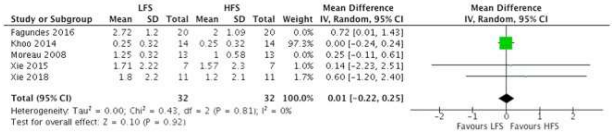
a Tremor subscores of UPDRS III (both on and off)



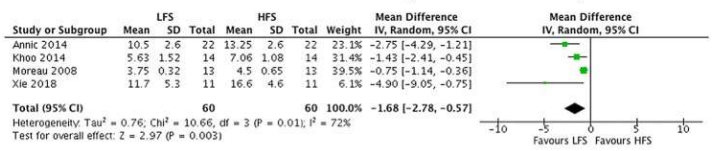
b Tremor subscores of UPDRS III (washed out)



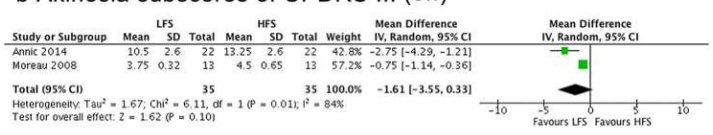
c Tremor subscores of UPDRS III (on)



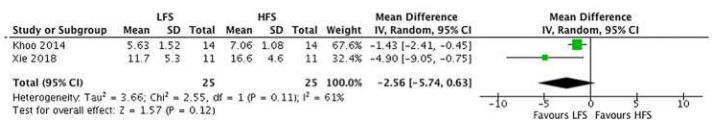
a Akinesia subscores of UPDRS III (both on and off)



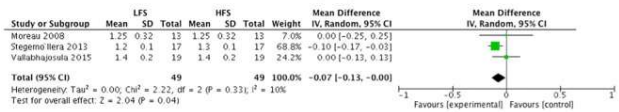
b Akinesia subscores of UPDRS III (off)



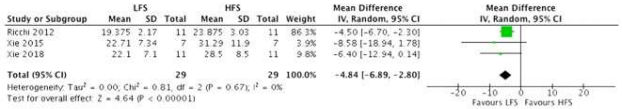
c Akinesia subscores of UPDRS III (on)



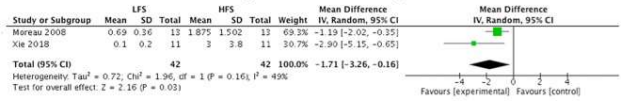
a Gait subscores of UPDRS III (off)



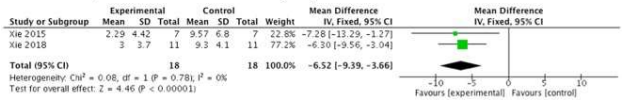
b SWS complete time (on)



c SWS number of FOG (both on and off)



d FOG questionnaire score (on)



Tremor – high frequency (>100Hz – usually 130 or 150)

Akinesia/gait/FroG – low frequency (<100Hz – usually 60 or 80)

Very low frequency (ie 5-10Hz) worsens motor symptoms

There may be a tradeoff between low frequency and tremor control

Su D, Chen H, Hu W, Liu Y, Wang Z, Wang X, Liu G, Ma H, Zhou J, Feng T. Frequency-dependent effects of subthalamic deep brain stimulation on motor symptoms in Parkinson's disease: a meta-analysis of controlled trials. Sci Rep. 2018 Sep 27;8(1):14456.

Goals for interleaving/ multistim set

- to use 2 contacts that optimally improve 2 specific symptoms but have different therapeutic windows
- to avoid side effects related to current spreading to nearby areas
- to increase frequency in a small region
- to stimulate a larger target area

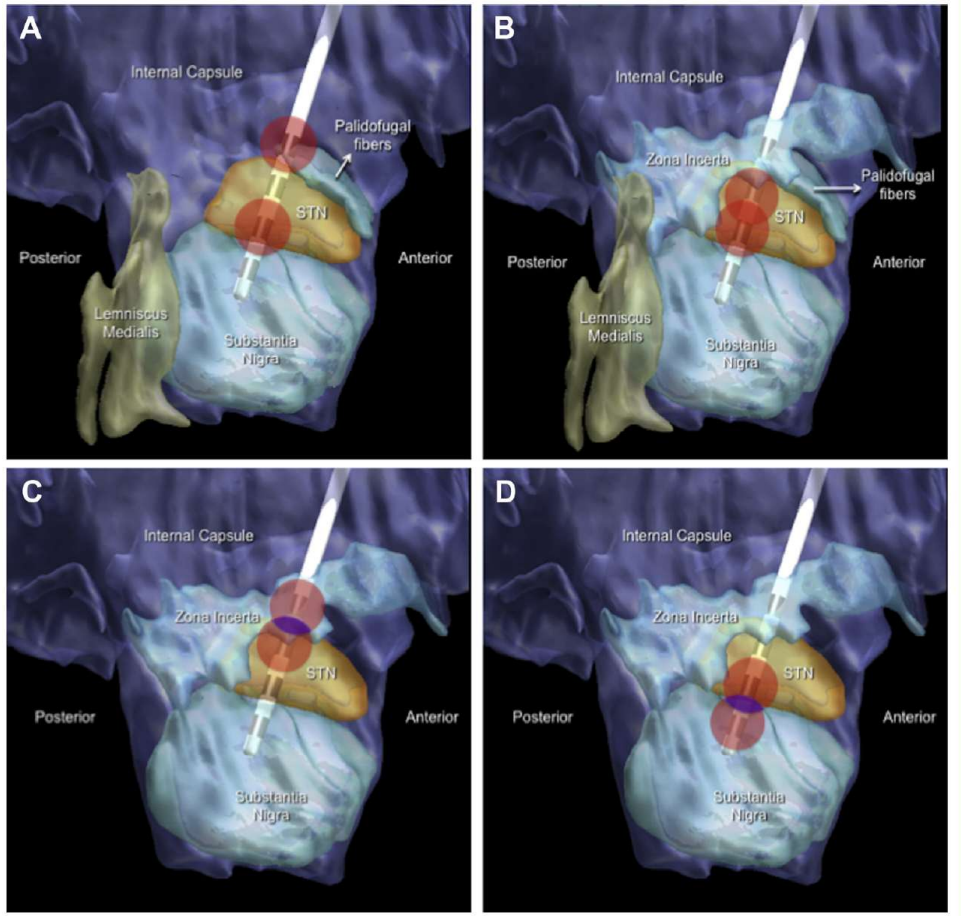
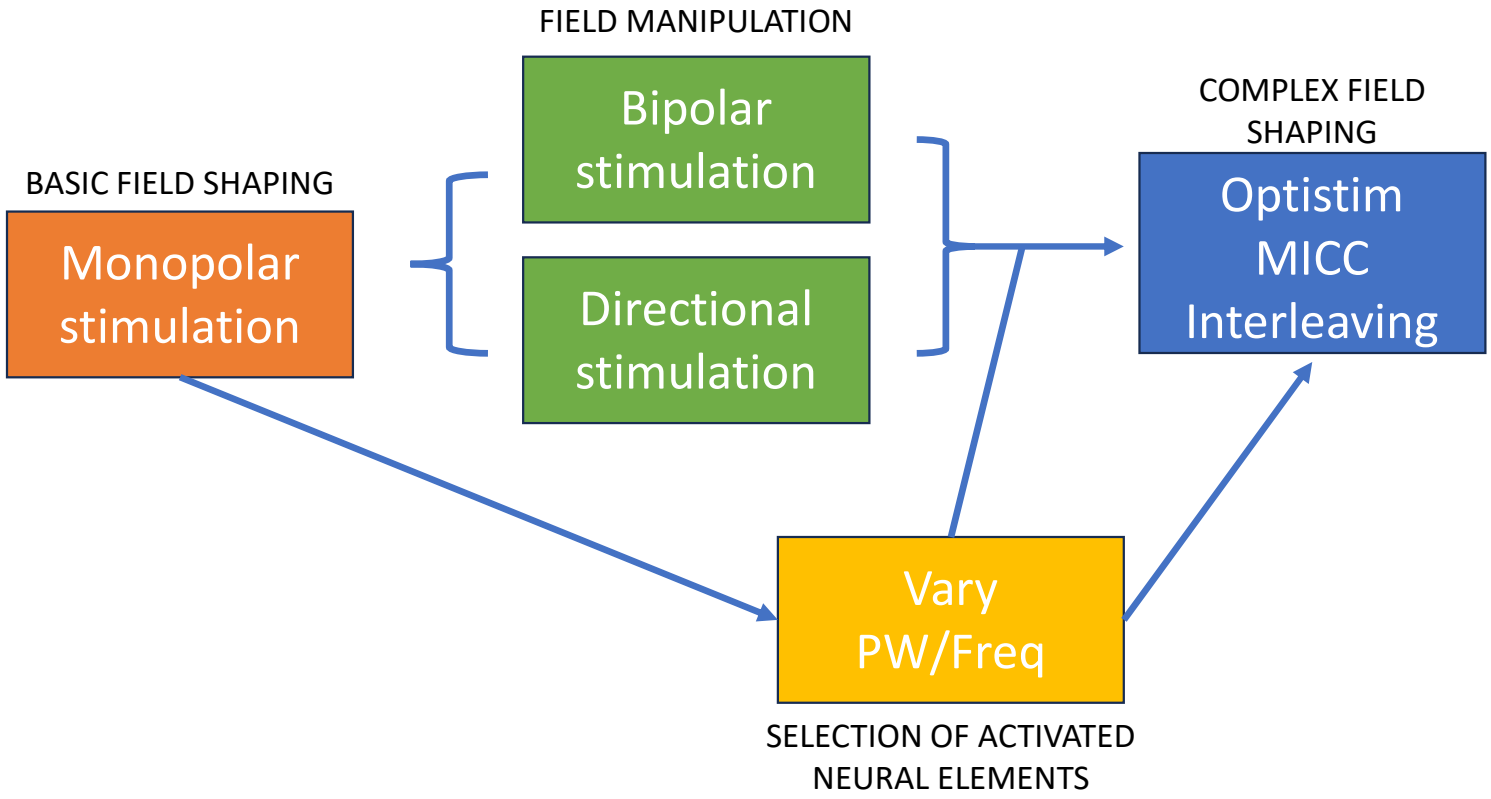


Figure 1. Anatomic illustration of subthalamic nucleus (STN) and its adjacent structures. (**A**) Pallidofugal fibers leaving the globus pallidus internus pass above the STN and could be reached using the most dorsal contact, whereas a more ventral contact would cover the STN area in cases of dyskinesias. (**B**) Stimulation area restricted inside the dorsolateral STN without compromising unwanted adjacent areas (e.g., the internal capsule and the leminiscus medialis) could be used to improve parkinsonism without stimulation-induced side effects. (**C**) Using adjacent contacts in high frequency creates an overlap area where frequency is doubled and can aid in tremor control, as well as targeting the zona incerta, an area above the STN. (**D**) Stimulation of the substantia nigra simultaneously with STN stimulation to improve gait disorders. Figures assembled using Lead-DBS.

França C et al. Neurosurg. 2019 Oct;130:e786-e793.

DBS optimization:
fine tuning to achieve optimal results



Recommendations

- Be systematic
  - Document well
- Understand anatomy and pathways
- Don’t fiddle
- Be wary of “rampism”
  - Not everything can be fixed with a stim adjustment
  - A stim adjustment is not always appropriate
  - Set expectations