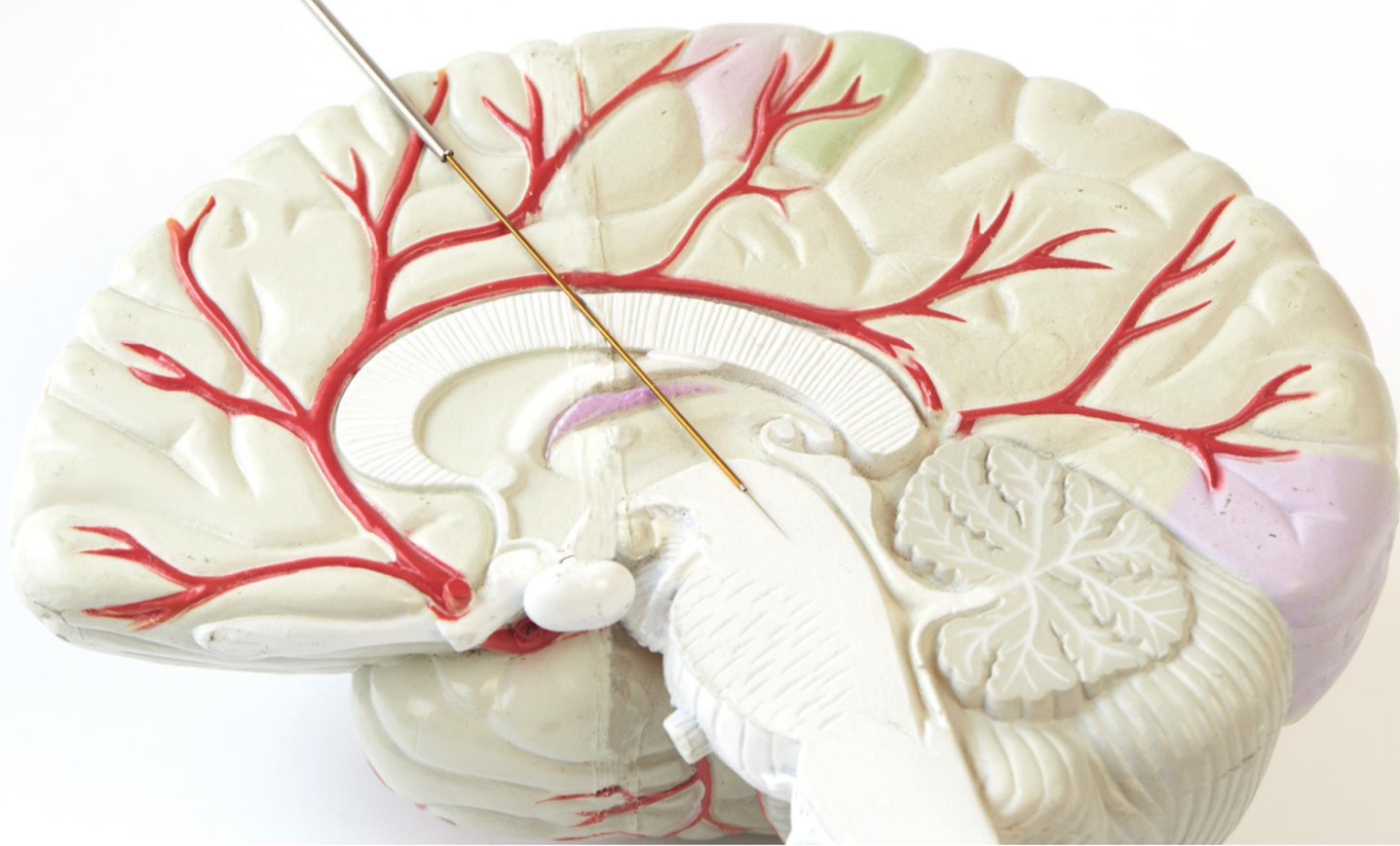




5th Neuromodulation School for Movement Disorders

New York, New York, USA | August 13-14, 2026



International Parkinson and
Movement Disorder Society
Pan American Section



Focused ultrasound for the treatment of movement disorders

PRESENTED BY: Daniel Cleary, MD, PhD
Assistant Professor
OHSU Neurosurgery

5th Neuromodulation School for Movement Disorders

New York, New York, USA | August 13-14, 2026



International Parkinson and
Movement Disorder Society
Pan American Section

- Outline
 - History of surgical interventions for movement disorders
 - Essentials of Focused Ultrasound
 - Essential Tremor
 - Benefits and side effects
 - Targeting
 - Measuring tremor
 - Parkinson's Disease
 - VIM vs PTT vs Pallidotomy
 - Benefits and side effects

Disclosures

- Consulting for Insightec
- Consulting for Biotronik

Essential Tremor

- Benign tremor, familial tremor, idiopathic tremor, **intention tremor**
- Affects over 10 million Americans
- Middle or later years, progressive
- Meds: Propanolol, primidone, gabapentin



Parkinson's Disease

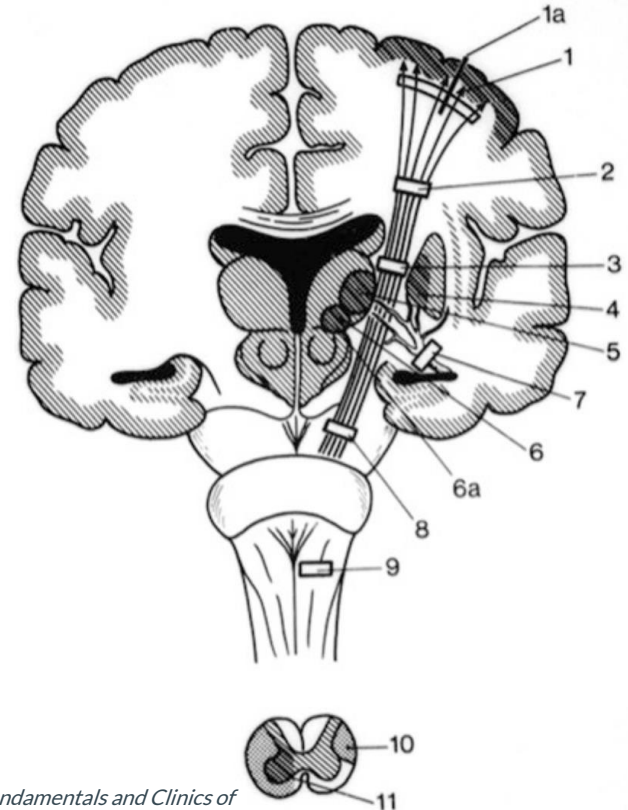
- “Paralysis agitans”, described by James Parkinson in 1817
- Affects > 1 million Americans
- Michael J. Fox, Muhammad Ali
- **Resting tremor**, bradykinesia, rigidity, stooped posture, **progressive**
- **Meds:** dopamine replacement/agonists



Surgical treatment of tremor



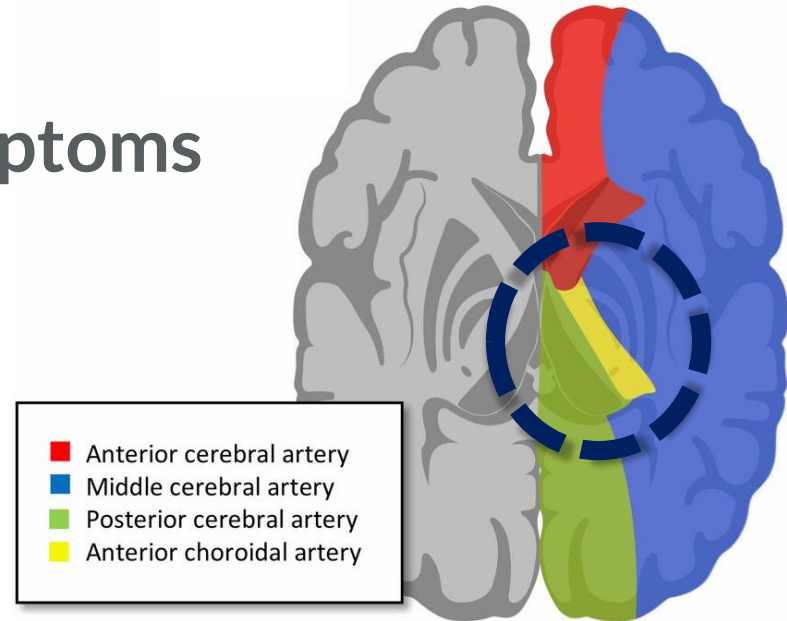
- 1817: Tremor improved after hemiparetic stroke (Parkinson)
- 1890: Removal motor cortex
- 1912: Cutting nerve roots
- 1937: Premotor cortex, brainstem, spinal cord
- 1948 – 1960: 6000 lesions for movement disorder
- 1952: **Irving Cooper**, accidental stroke



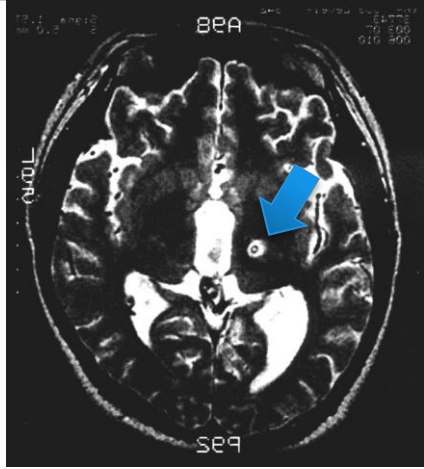
Temel, Yasin, et al., eds. *Fundamentals and Clinics of Deep Brain Stimulation: An Interdisciplinary Approach*. Springer Nature, 2020.



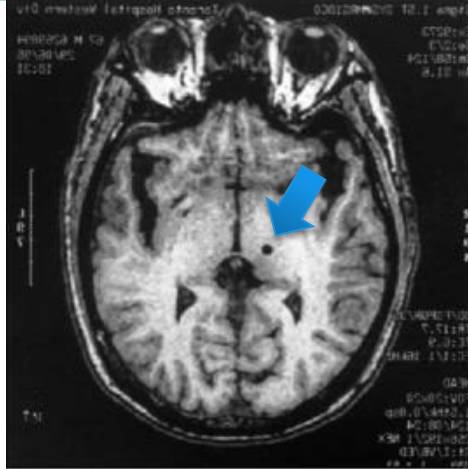
- Anterior choroidal artery stroke
 - Reduction in motor symptoms
 - Tremor relief
 - No paralysis



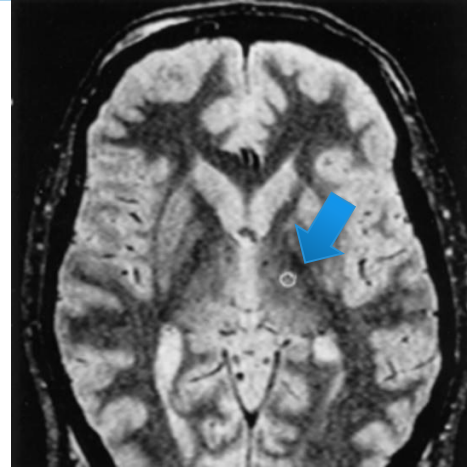
Basis of procedural treatments



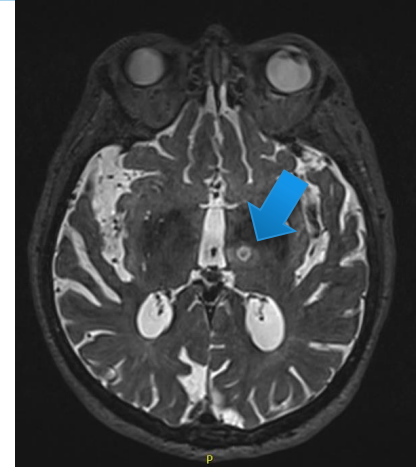
Radiofrequency
Lesion



Deep Brain
Stimulation



Gamma Knife



Focused
Ultrasound

Kim, M. C., et al. "Vim thalamotomy for Holmes' tremor secondary to midbrain tumour." *Journal of Neurology, Neurosurgery & Psychiatry* 73.4 (2002): 453-455.

Honey, Christopher, R. E. Gross, and A. M. Lozano. "New developments in the surgery for Parkinson's disease." *Canadian journal of neurological sciences* 26.S2 (1999): S45-S52.

Duma, Christopher M., et al. "Gamma knife radiosurgery for thalamotomy in parkinsonian tremor: a five-year experience." *Journal of neurosurgery* 88.6 (1998): 1044-1049.

“Sooner or later, everything old is new again.”

The Placement of Stereotaxic Lesions for Involuntary Movements other than in Parkinson's Disease

[J. Andrew](#)^{3,5}, [J. M. Rice Edwards](#)^{3,5} & [N. M. de Rudolf](#)^{3,4,5}

Conference paper

51 Accesses

Part of the [Acta Neurochirurgica](#) book series (STEREOTACTIC, volume 21)

Abstract

This report concerns 37 thalamotomies in 25 patients. Table 1 shows the various diagnoses.

1974

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

A Pilot Study of Focused Ultrasound Thalamotomy for Essential Tremor

W. Jeffrey Elias, M.D., Diane Huss, P.T., D.P.T., N.C.S., Tiffini Voss, M.D., Johanna Loomba, B.S., Mohamad Khaled, M.D., Eyal Zadicario, M.Sc., Robert C. Frysinger, Ph.D., Scott A. Sperling, Psy.D., Scott Wylie, Ph.D., Stephen J. Monteith, M.D., Jason Druzgal, M.D., Ph.D., Binit B. Shah, M.D., Madaline Harrison, M.D., and Max Wintermark, M.D.

2013



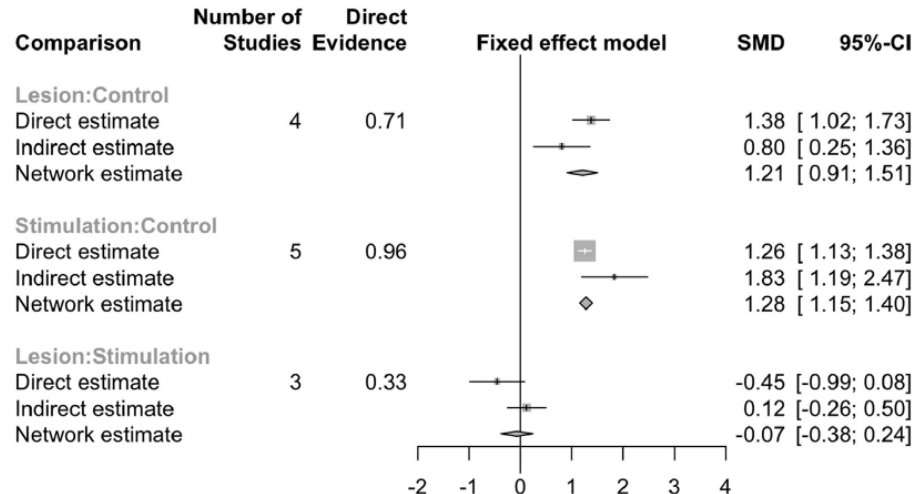
Efficacy of Lesion vs Stimulation

Outcomes in Lesion Surgery versus Deep Brain Stimulation in Patients with Tremor: A Systematic Review and Meta-Analysis

Yuksel Altinel¹, Fahad Alkhalfan¹, Nidan Qiao^{1,2}, Marko Velimirovic³

WORLD NEUROSURGERY 123: 443-452, MARCH 2019

Combined comparison:



“This meta-analysis showed that [lesion] and DBS were equally effective in tremor control.”

“We found no differences in quality of life, cognitive, or neuropsychiatric function between the 2 treatments.”

Procedural Treatments

	Radiofrequen cy Ablation	Deep Brain Stimulation	Gamma Knife	Focused Ultrasound
Procedure				
Procedural Risk				
Outcomes				
Side effects				
Laterality				
Time to benefit				

Benefits of Focused Ultrasound

- Minimally invasive
 - No anesthesia
 - No incisions
 - Home the same day
- Age and medical problems less limiting
- One-time treatment
- No implants
- Immediate improvement in quality of life

Focused Ultrasound Timeline

2005

First brain
treatment with
intact skull

2016

FDA approval
for VIM for ET

2018

FDA approval for
VIM for PD

2021

FDA approval
for pallidotomy

2022

FDA approval
for bilateral VIM

2025

FDA approval
for bilateral PTT

Focused Ultrasound: 1024 Ultrasonic Beams

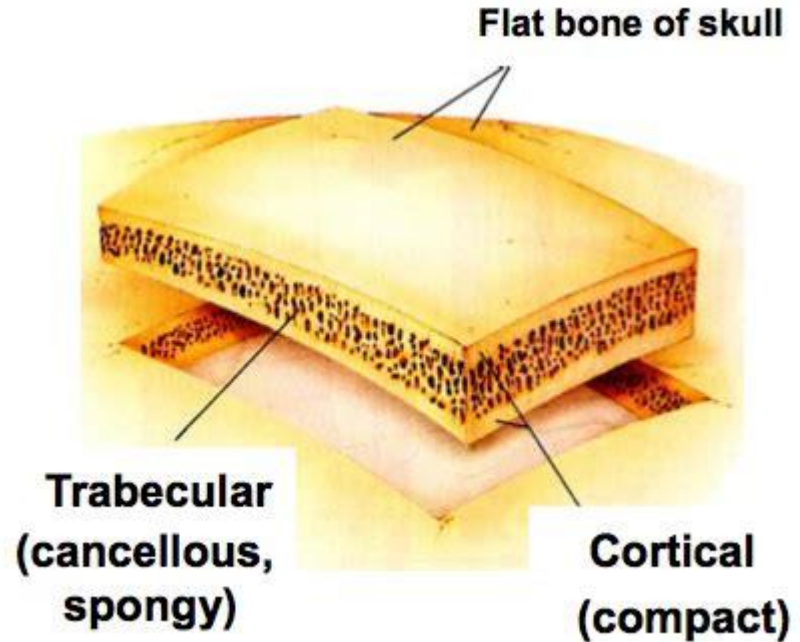


Who can get FUS thalamotomy?

- Patients with disabling/debilitating tremor from:
 - Essential Tremor (ET)
or
 - Tremor-Dominant Parkinson's Disease (TDPD)
- Medications ineffective
- Able to get MRI
- Willing to shave head
- Skull density ratio > **0.35**

Skull Density Ratio (SDR)

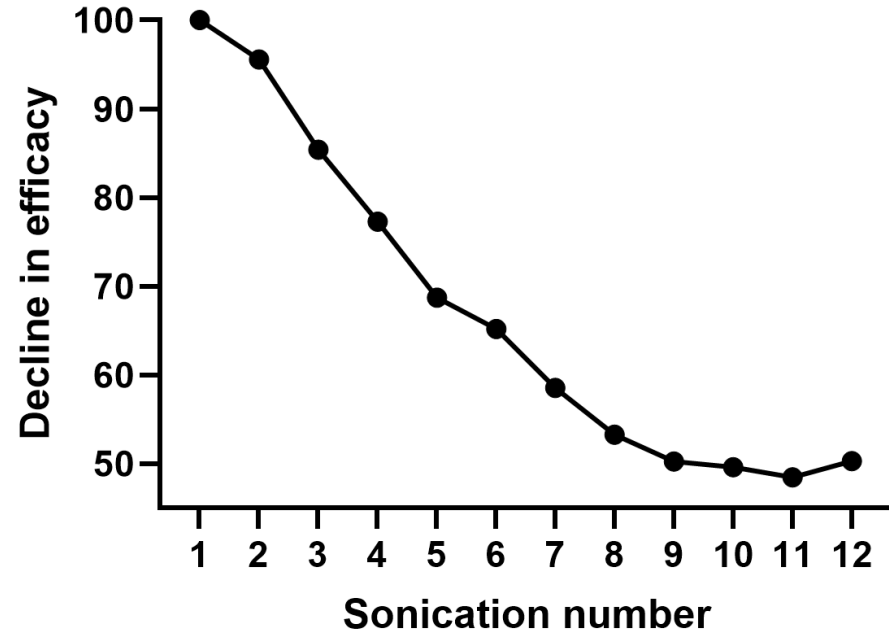
- Density of cancellous:cortical bone
- Acceptable: > 0.4
- Ideal: > 0.5
- Lowest treated: 0.33
- Low SDR:
 - Dispersal of energy
 - Less efficacy
 - More side effects



Sonication efficiency

- Efficiency – C / kJ
 - Heat produced / energy input
- More sonications = more energy
- More energy =
 - More pain
 - More thermal spread
 - More side effects

So work efficiently!



Essential Tremor

Essential Tremor Outcomes

- Tremor relief at 5 years: **73% tremor improvement (CRST)**
- Short-term adverse effects:
 - Headache: 51%
 - Numbness/tingling: 33%
 - Gait/imbalance: 26%
- Long-term adverse effects:
 - **No severe long-term adverse effects**
 - Mild/moderate adverse effects:
 - Numbness /tingling (10%)
 - Imbalance/gait difficulty (5%)
 - Weakness (2%)
 - Lack of coordination (3%)



Magnetic resonance imaging–guided focused ultrasound thalamotomy for essential tremor: 5-year follow-up results

G. Rees Cosgrove, MD,¹ Nir Lipsman, MD, PhD,² Andres M. Lozano, MD, PhD,³ Jin Woo Chang, MD, PhD,⁴ Casey Halpern, MD,⁵ Pejman Ghanouni, MD, PhD,⁶ Howard Eisenberg, MD,⁷ Paul Fishman, MD, PhD,⁸ Takaomi Taira, MD, PhD,⁹ Michael L. Schwartz, MD, MSc,² Nathan McDannold, PhD,¹⁰ Michael Hayes, MD,¹¹ Susie Ro, MD,¹² Binit Shah, MD,¹³ Ryder Gwinn, MD,¹⁴ Veronica E. Santini, MD, MA,¹⁵ Kullervo Hynynen, PhD,¹⁶ and W. Jeff Elias, MD¹⁷

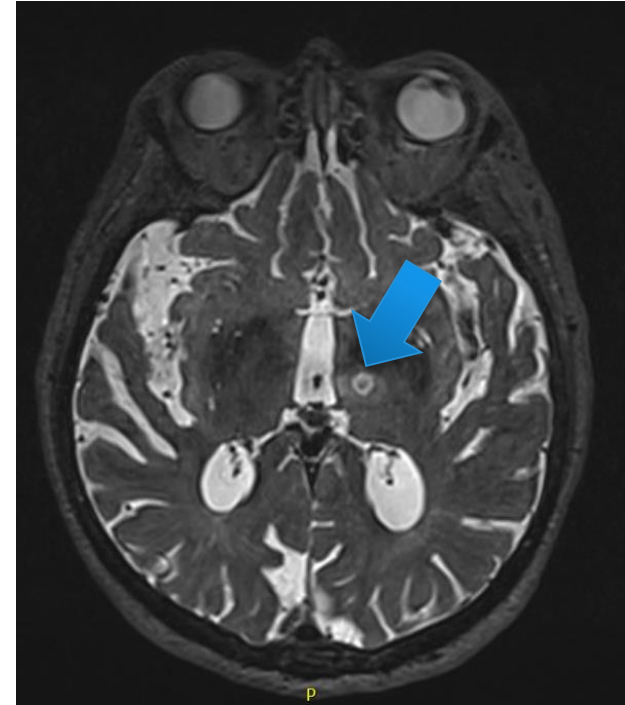
DBS randomized trial, NEJM 2006:

- 13% serious adverse effects
- 64% any adverse effects
- 1 death

What is this target?

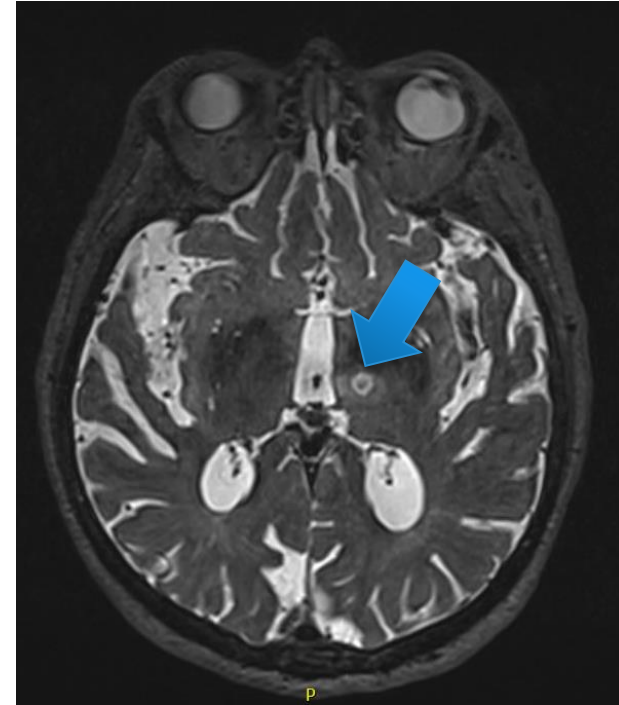


- Thalamus
 - Sensory (and motor) relay
- Ventral intermediate nucleus (VIM)
- Contains neurons and fibers

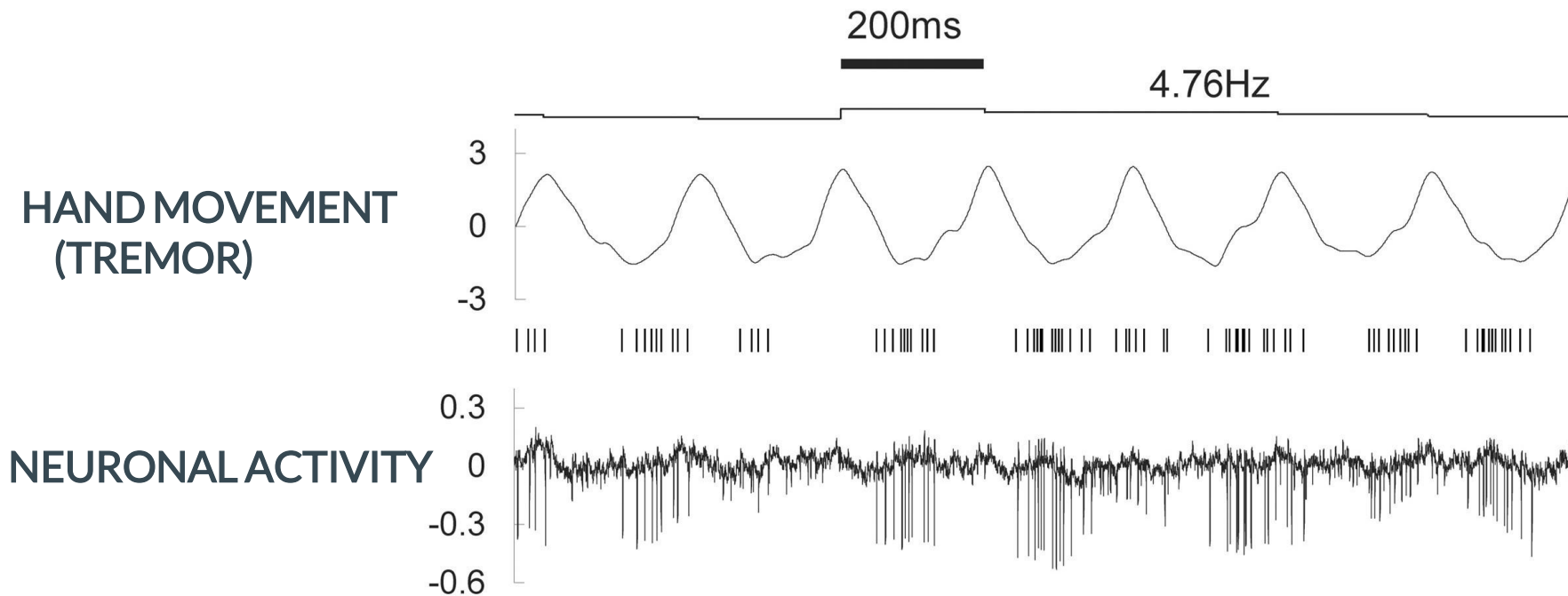


Open questions

- VIM: a key relay or the primary site?
- Mechanism of improvement?
 - DBS and lesion similar
- Pathogenesis of tremor

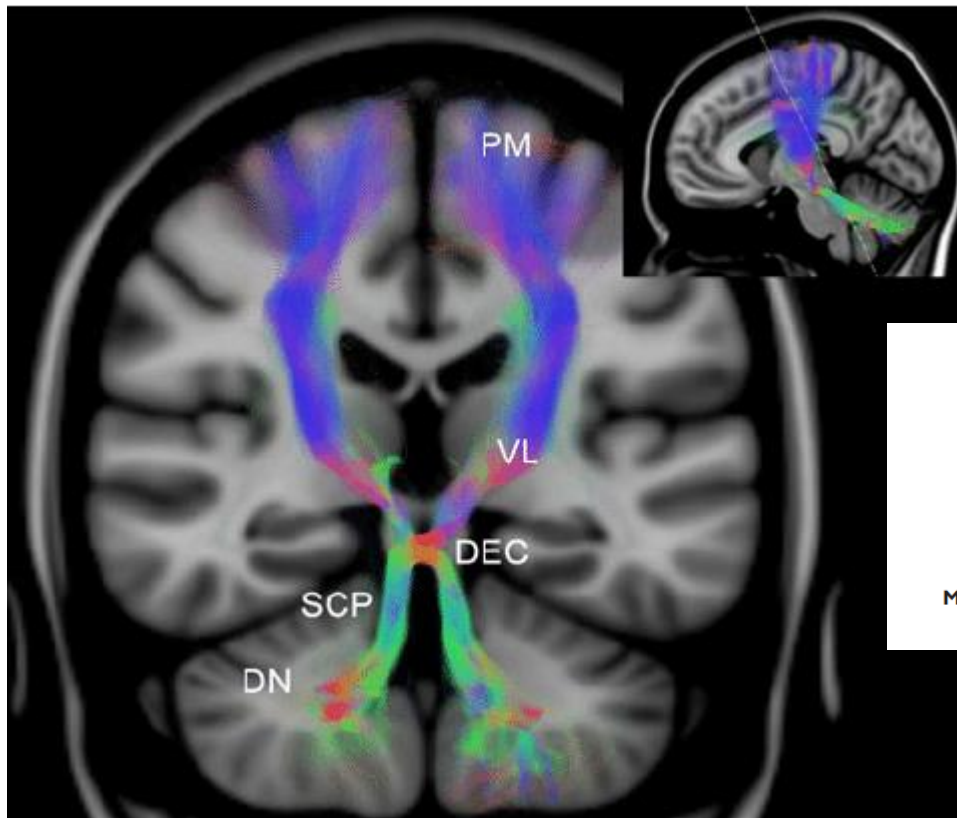


Targeting VIM: neurons vs fibers?



Milosevic, Luka, et al. "Physiological mechanisms of thalamic ventral intermediate nucleus stimulation for tremor suppression." *Brain* 141.7 (2018): 2142-2155.

Targeting VIM: neurons vs fibers?



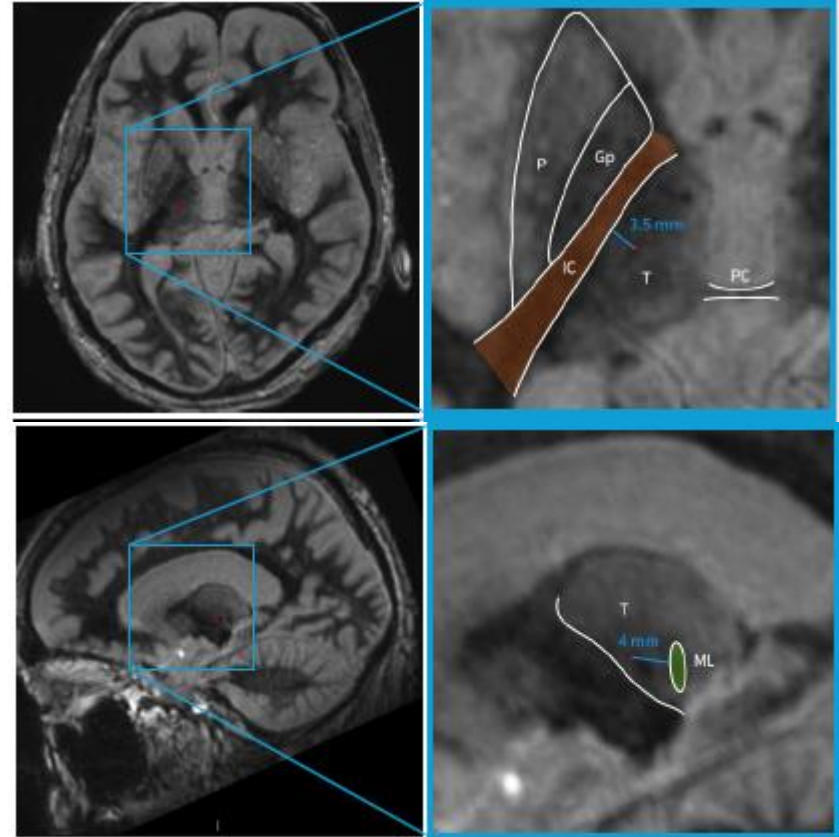
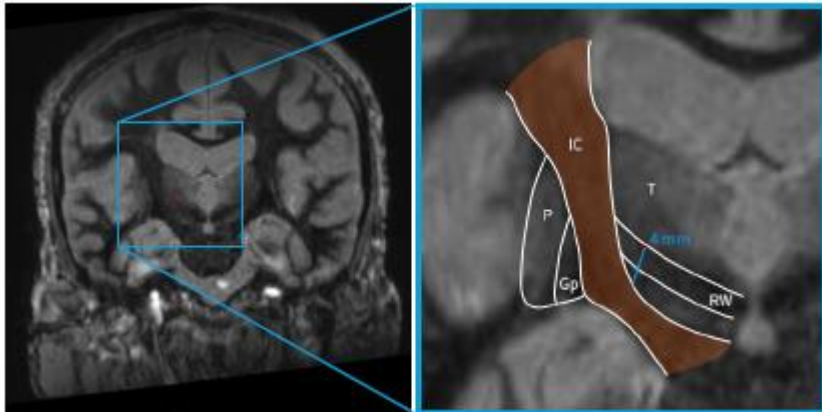
Essential Tremor Is Associated With Disruption of Functional Connectivity in the Ventral Intermediate Nucleus—Motor Cortex—Cerebellum Circuit

Weidong Fang,^{1*} Huiyue Chen,¹ Hansheng Wang,¹ Han Zhang,²
Munankami Puneet,¹ Mengqi Liu,¹ Fajin Lv,¹ Tianyou Luo,¹ Oumei Cheng,³
Xuefeng Wang,³ and Xiurong Lu³

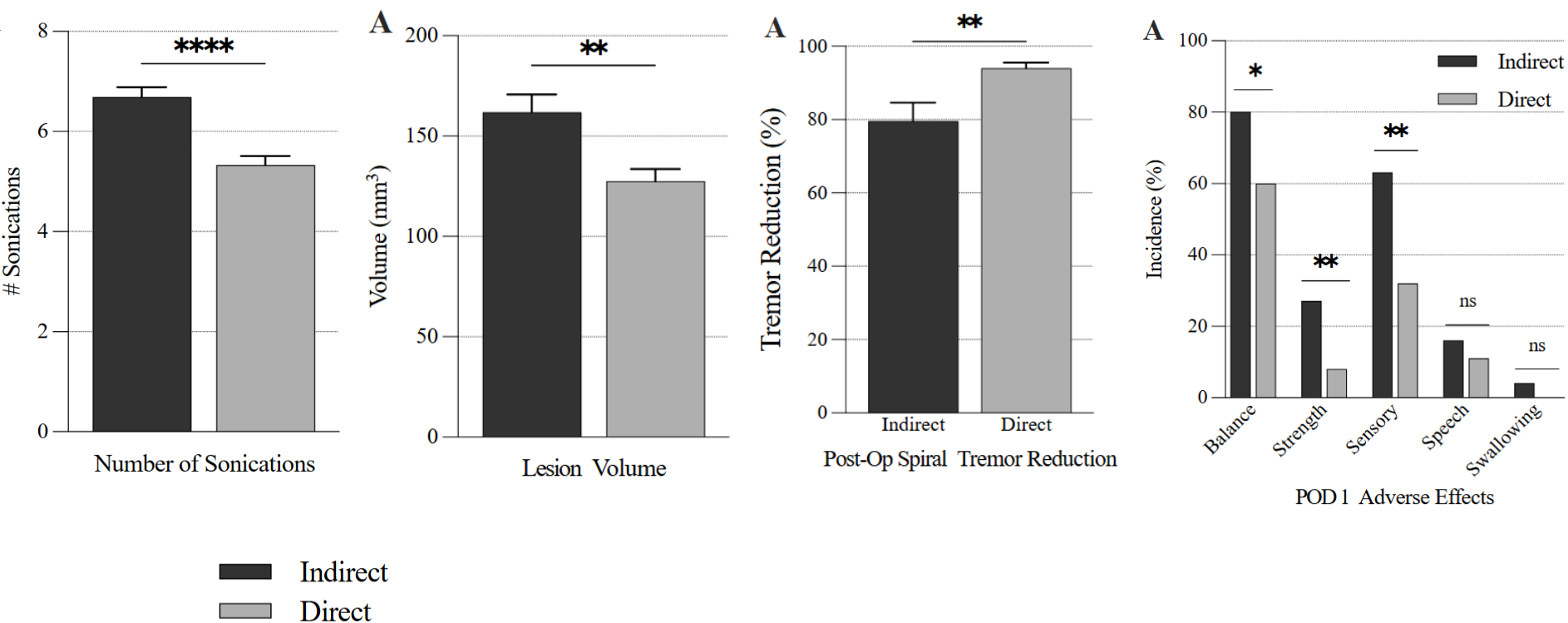
van Baarsen, Kirsten, et al. "Tractography demonstrates dentate-rubro-thalamic tract disruption in an adult with cerebellar mutism." *The Cerebellum* 12 (2013): 617-622.

Targeting DRRT improves outcomes

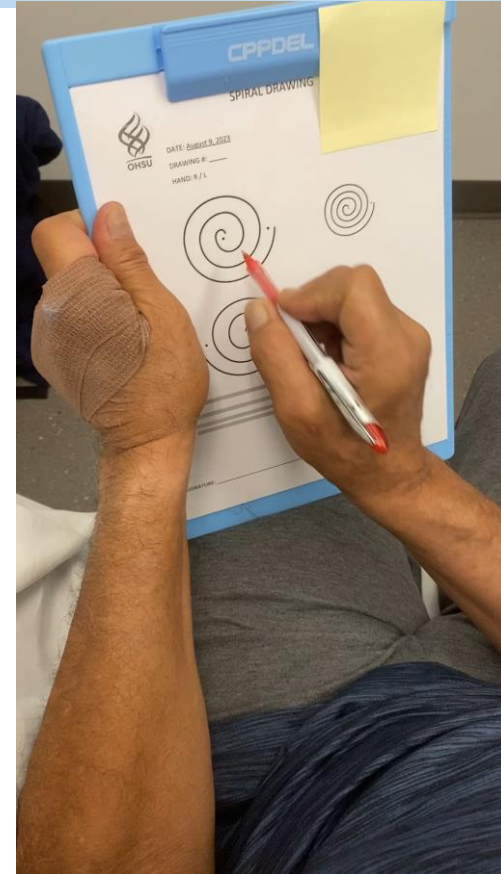
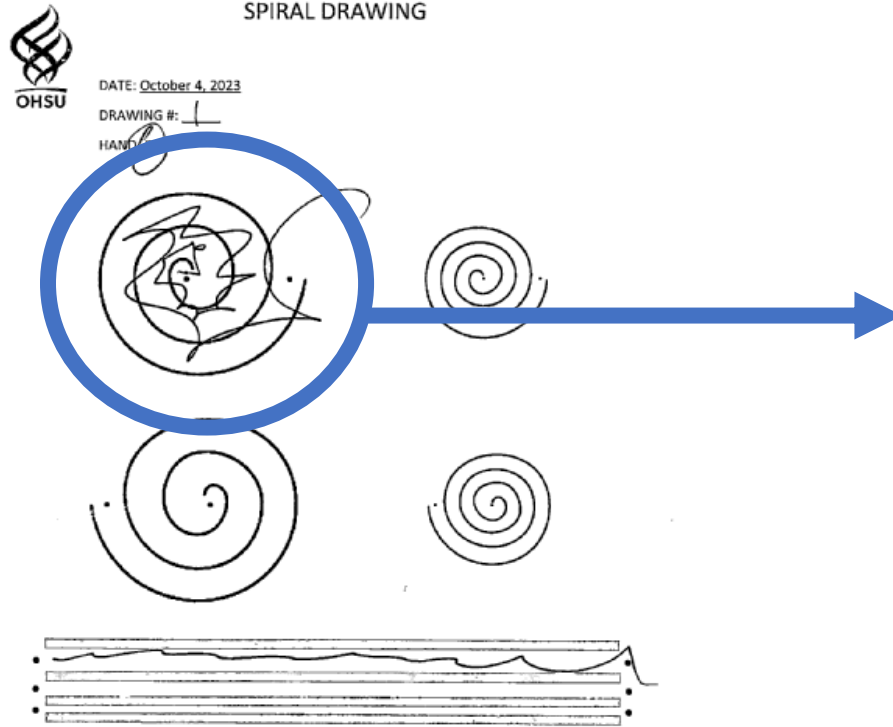
- FGATIR: white-matter null MRI sequence



Direct targeting DRRT improves outcomes



Measuring tremor



Progression of improvement

7:00 am



7:45 am



8:00 am



8:15 am



8:18 am



8:20 am



8:25 am



8:30 am

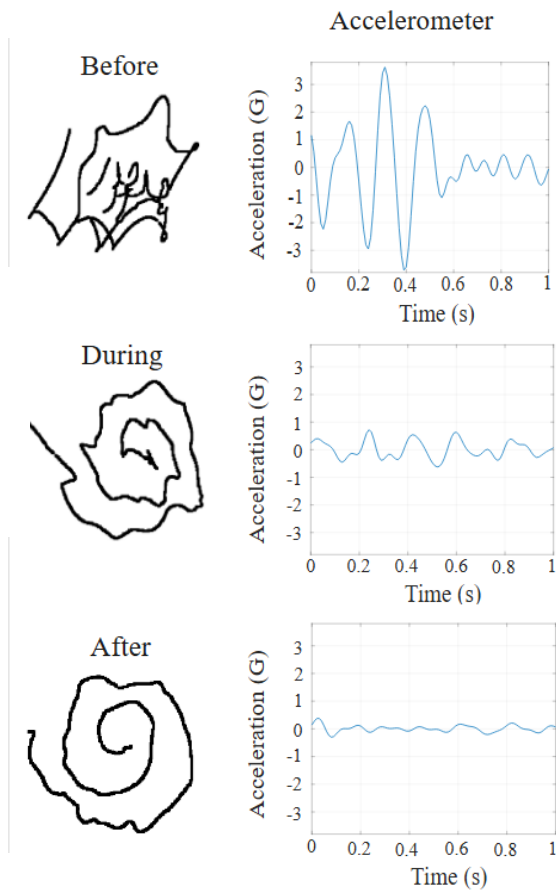
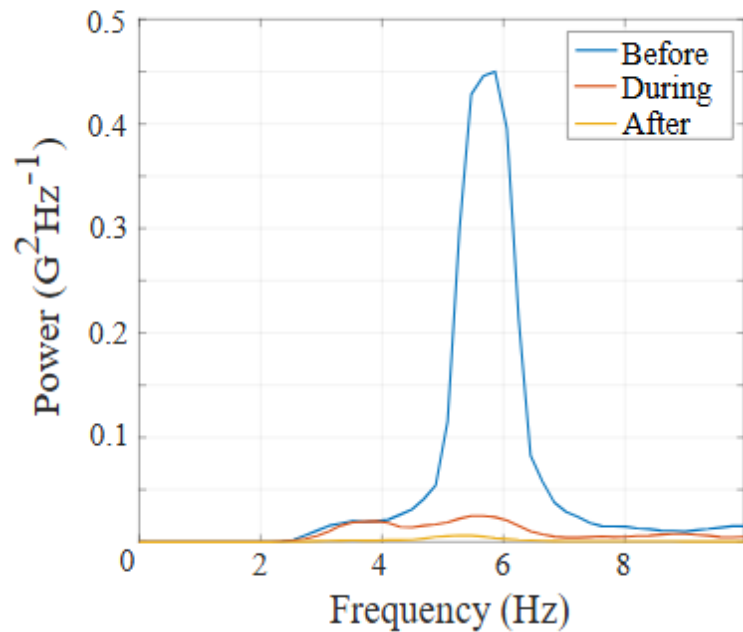


Objective tremor measurement

- Numerous attempts to quantify and categorize tremor
- We use a pen-mounted accelerometer with a tablet
 - Higher accuracy
 - More sensitive detection
 - Objective improvement



Objective tremor measurement



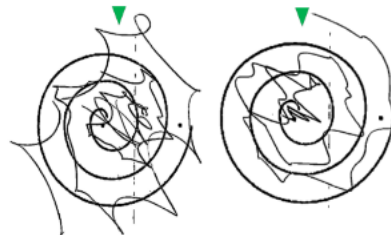
Objective tremor measurement



Pre-Procedure

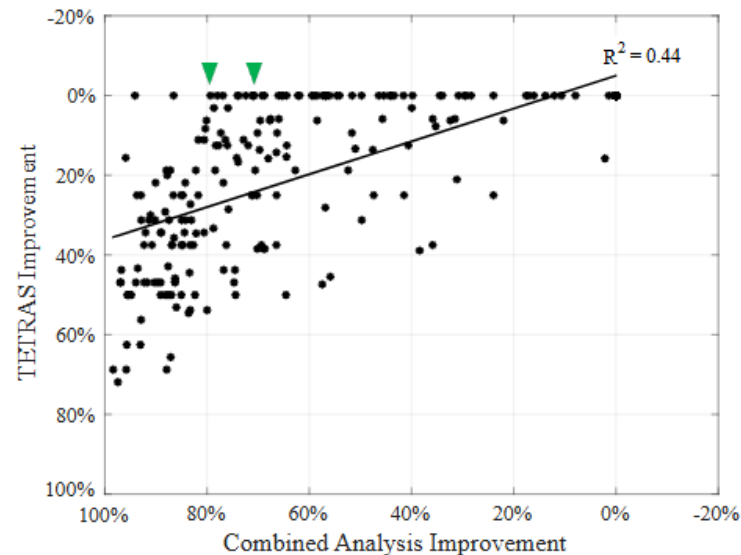
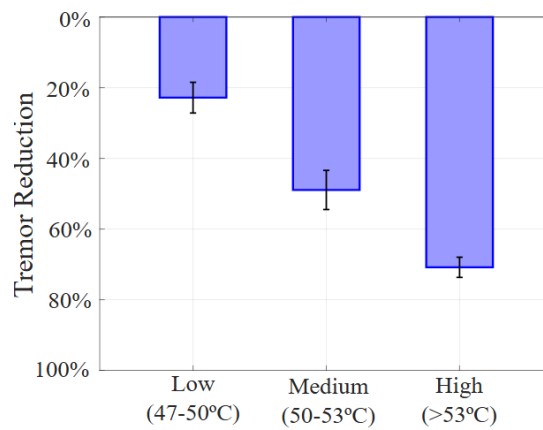


During Procedure



Post-Procedure

TETRAS:	4 (severe)	4 (severe)	3.5 (severe)
Accelerometer:	20% worse	70% better	80% better



Bilateral FUS thalamotomy

RESEARCH ARTICLE

Bilateral Focused Ultrasound Thalamotomy for Essential Tremor (BEST-FUS Phase 2 Trial)

CME

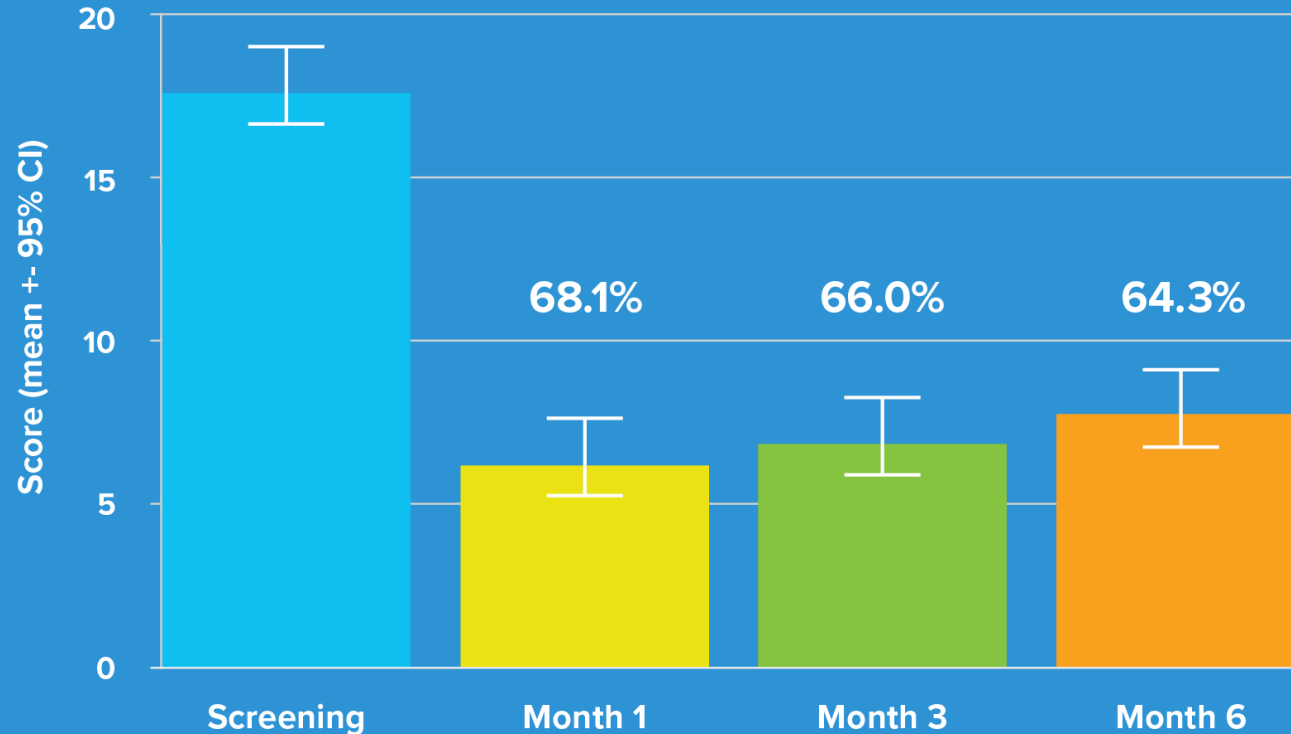
Christian Iorio-Morin, MD, PhD, FRCS(C),^{1,2}  Kazuaki Yamamoto, MD,² Can Sarica, MD,² Ajmal Zemmar, MD,^{2,3}
Mathieu Levesque, MD, FRCP(C),⁴ Simon Brisebois, MD, MSc, FRCS(C),⁵ Jurgen Germann, PhD,²
Aaron Loh, MB, BCh, BAO,² Alexandre Boutet, MD, PhD,^{2,6} Gavin J.B. Elias, BA,² Paula Azevedo, MD,⁷
Elizabeth Adam,^{1,2} Urmi Patel, BSc,² Martha Lenis, BHA, CCRP,² Suneil K. Kalia, MD, PhD, FRCS(C),^{2,8}
Mojgan Hodaie, MD, MSc, FRCS(C),² Alfonso Fasano, MD, PhD,^{7,8} and Andres M. Lozano, MD, PhD, FRCS(C)^{2*}

- Preliminary trial (2021): 10 patients
- All had significant improvement in tremor
- 7 patients with mild adverse effects
- Pivotal follow-up, 51 patients/7 centers
- Approved 2022, wait 9 months between sides
 - Exclude dysarthria, dysphagia, caution with PD

Bilateral FUS thalamotomy

- Tremor/Motor Function - CRST Parts A+B

$P < 0.001$

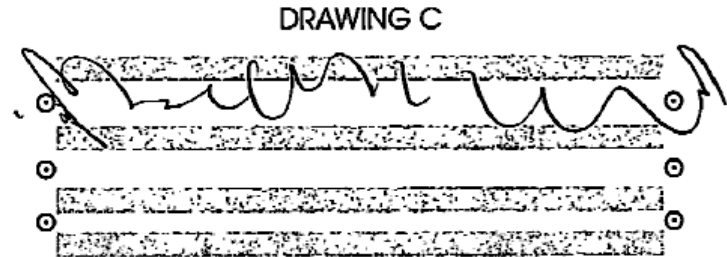
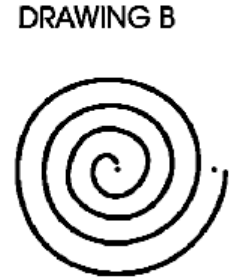


Bilateral FUS thalamotomy

<u>Adverse Events</u> 85% mild 15% moderate 2% severe	Prevalence Ongoing >6M	
	Study 1: Unilateral cohort	Study 2: Contralateral cohort
Gait disturbance / Ataxia / Imbalance)	7 (13%)	13 (25%)
Dysarthria	1 (2%)	8 (16%)
Taste Disturbance (Dysgeusia/Hypogeusia)	2 (4%)	11 (22%)
Sensory Deficits (Paresthesia / Numbness)	11 (20%)	9 (18%)
Dysphagia	1 (2%)	3 (6%)

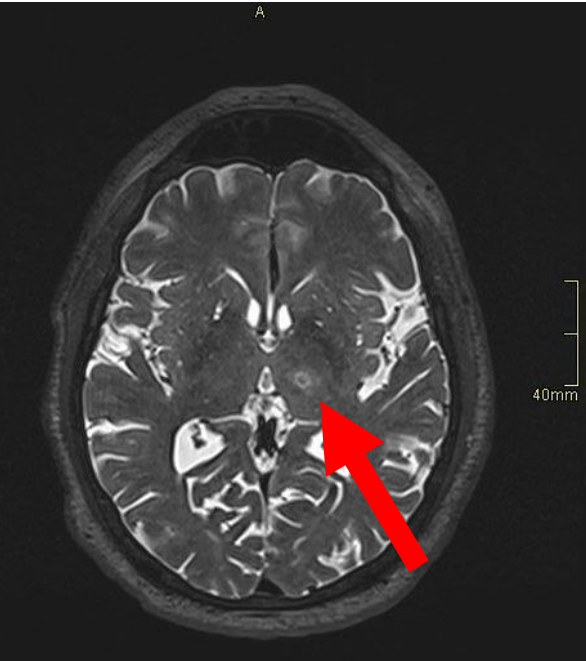
Example case:

- 58 year old man
- Metal fabricator, forced to retire
- Primidone & propranolol no longer effective



Example case:

- Uncomplicated left FUS thalamotomy
- Transient gait/balance issues, resolved by 3 months



Example case:

1 year later, MRI for evaluation of contralateral treatment

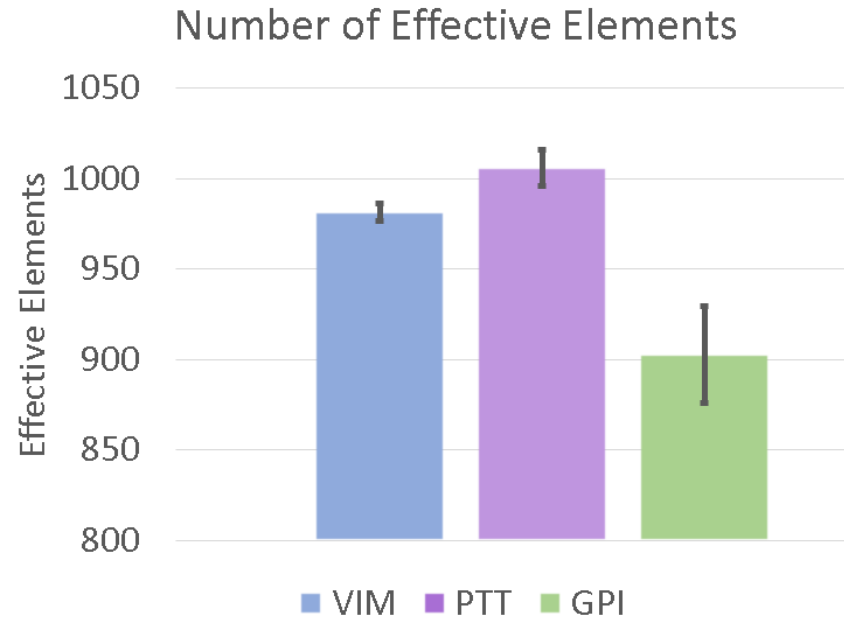


ET example case



Parkinson's Disease

- VIM thalamotomy
- Pallidotomy
- Pallidothalamic tractotomy



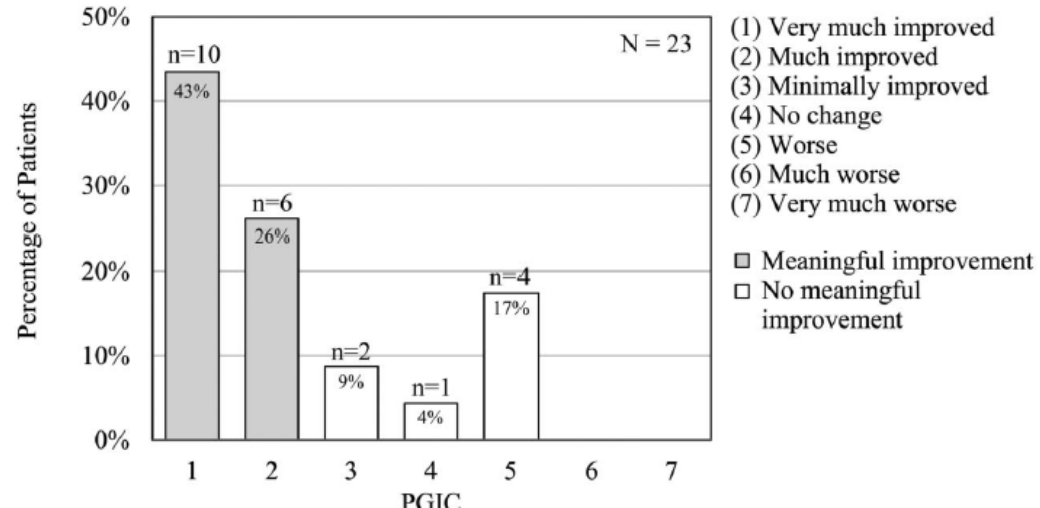
VIM for Tremor Dominant PD (TDPD)

Patient-Reported Outcomes After Focused Ultrasound Thalamotomy for Tremor-Predominant Parkinson's Disease

Georgios A. Maragkos, MD [✉], Jacob Kosyakovsky, BS[†], Patricia Zhao, BS[†], Kathryn N. Kearns, MD*, Shelly Rush-Evans, MSN, RN, CNRN*, Shayan Moosa, MD*, W. Jeffrey Elias, MD*

Neurosurgery, 2023

- 29 patients, 16 months follow-up
- 93% had immediate improvement
- 63% sustained improvement
- 17% had full tremor recurrence
- 38% had side effects (mostly mild)
- 69% had quality of life improvement



Pallidotomy (GPi)

The NEW ENGLAND JOURNAL *of* MEDICINE

ESTABLISHED IN 1812

FEBRUARY 23, 2023

VOL. 388 NO. 8

Trial of Globus Pallidus Focused Ultrasound Ablation in Parkinson's Disease

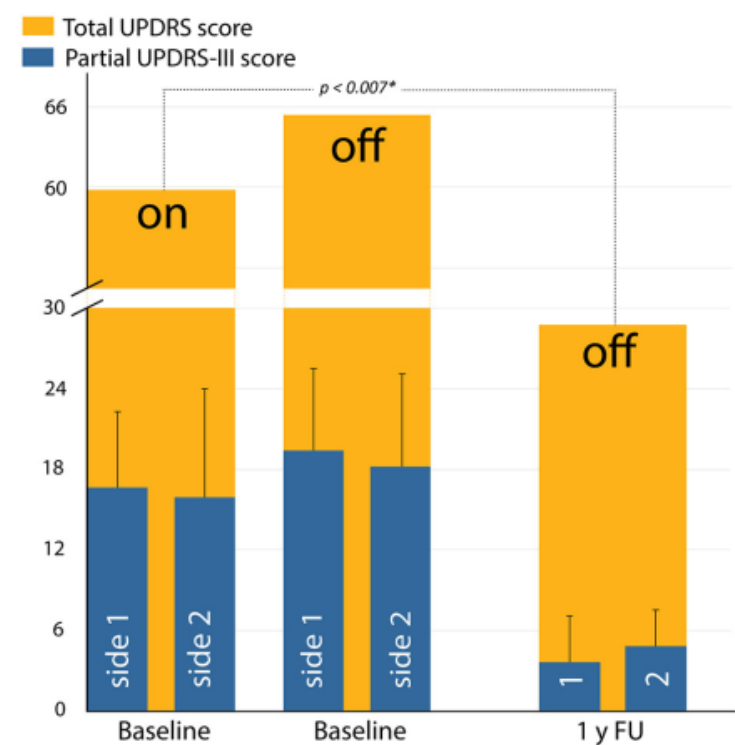
Vibhor Krishna, M.D., Paul S. Fishman, M.D., Ph.D., Howard M. Eisenberg, M.D., Michael Kaplitt, M.D., Ph.D., Gordon Baltuch, M.D., Jin Woo Chang, M.D., Wei-Chieh Chang, M.D., Raul Martinez Fernandez, M.D., Marta del Alamo, M.D., Casey H. Halpern, M.D., Pejman Ghanouni, M.D., Ph.D., Roberto Eleopra, M.D., Ph.D., Rees Cosgrove, M.D., Jorge Guridi, M.D., Ryder Gwinn, M.D., Pravin Khemani, M.D., Andres M. Lozano, M.D., Ph.D., Nathan McDannold, Ph.D., Alfonso Fasano, M.D., Ph.D., Marius Constantinescu, M.D., Ilana Schlesinger, M.D., Arif Dalvi, M.D., and W. Jeff Elias, M.D.

- 94 patients (Randomized, 68 FUS, 24 sham)
- Adverse events:
 - Dysarthria (2x)
 - Gait disturbance (2x)
 - Loss of taste (2x)
 - Visual disturbance (1x)
 - Headache, nausea
- OHSU experience: cannot achieve temperature

Outcome	FUSA of the Globus Pallidus Internus (N = 65)	Sham Procedure (N = 22)	Difference (95% CI)	P Value
Primary outcome: response — no. (%)*	45 (69)	7 (32)	37 (15 to 60)†	0.003
Mean improvement in MDS-UPDRS IV score (95% CI)	5.1 (4.2 to 6.0)	0.3 (−0.9 to 1.5)	4.8 (3.1 to 6.5)	<0.001

What is the Pallidothalamic Tract

- Outflow from GPi to STN
- Fields of Forrel
 - Thalamic fasciculus (H1) and lenticular fasciculus (H2)
- Zona incerta
- Ventral oralis anterior (Voa)?
- Subthalamic nucleus?
- Multiple small cases studies, positive results
- PTT for PD FDA approved 2025



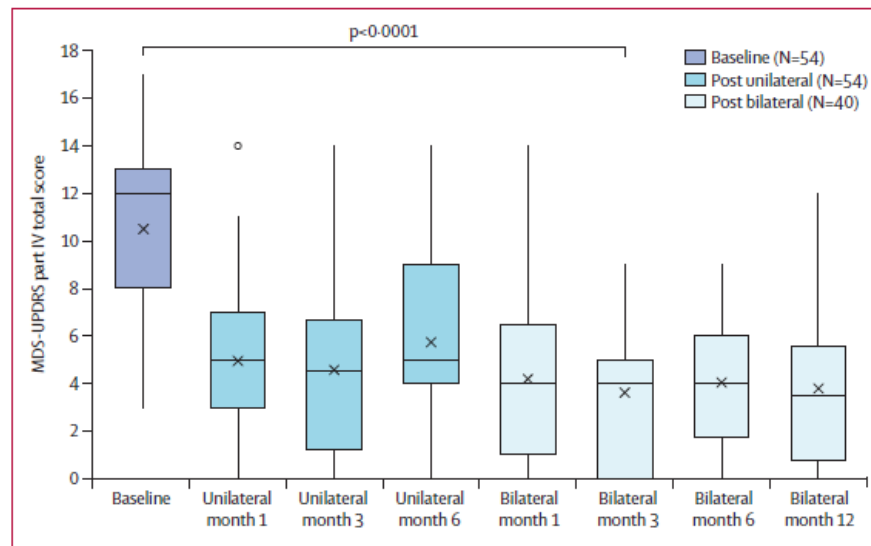
Gallay et al, Frontiers in Neurology, 2021

logy, 2025

Pivot Trial: Staged, bilateral PTT

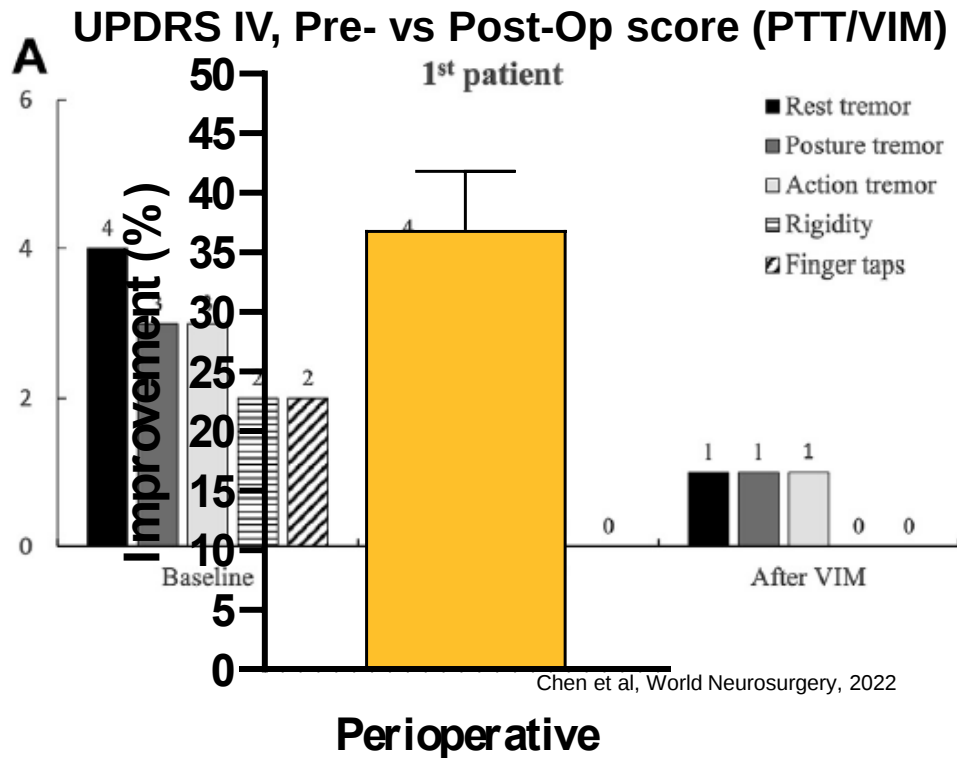
- 54 patients, 9 centers
- Unilateral treatment:
 - 39% acute adverse effects, 2% persistent
- Bilateral treatment:
 - 40 patients with bilateral
 - 55% acute adverse effects, 25% had persistent moderate/severe (speech, gait, balance)
 - 1 patient with anarthria
- 33 to 21 points (MDS-UPDRS III)
- 32% improvement

Safety and efficacy of staged, bilateral magnetic resonance-guided focused ultrasound pallidothalamic tractotomy for motor complications of Parkinson's disease: a prospective, multicentre, single-arm trial



Dual target: VIM + PTT

- VIM alone for PD:
 - Recurrence is common
- PTT alone for PD:
 - Good improvement rigidity/bradykinesia, less so tremor
- Combined VIM/PTT



Example case



Questions?

clearyd@ohsu.edu