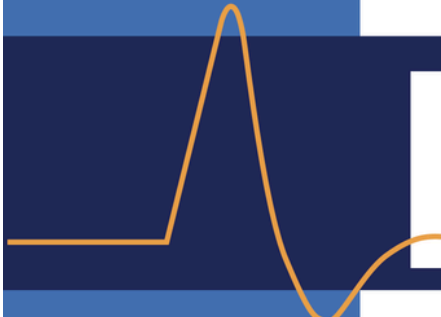




PULSE

TODAY'S AGENDA

1. NANS Publishes First Evidence-Based Clinical Practice Guidelines
2. Neuromodulation Without Boundaries
3. The Expanding Role of Focused Ultrasound in Movement Disorders
10. High-Intensity Focused Ultrasound Neuroablation
12. President's Vision
14. T7-T9 Spinal Cord Stimulation for Chronic Pelvic Pain
17. Restoring Function Across the Neural Axis

NANS Publishes First Evidence-Based Clinical Practice Guidelines

NANS has reached an important milestone with the publication of its **first evidence-based clinical practice guidelines**, providing recommendations for spinal cord stimulation (SCS) and peripheral nerve stimulation (PNS) in the treatment of chronic pain.

Published in *Neuromodulation: Technology at the Neural Interface*, the two guidelines are:

- **Evidence-Based Clinical Practice Guidelines on Epidural Stimulation for Chronic Pain: A Consensus Report from a Multispecialty Working Group from the North American Neuromodulation Society**
 - Published online September 4, 2026.
- **Evidence-Based Clinical Practice Guidelines on Implantable Peripheral Nerve Stimulation for Chronic Pain: A Consensus Report from a Multispecialty Working Group from the North American Neuromodulation Society**
 - Published online September 17, 2026.

Developed through a multiyear effort by two multidisciplinary [NANS Guideline Development Groups](#), the publications evaluate the available evidence, provide clinically meaningful recommendations, and identify important opportunities for future research.

Read the guidelines to explore the latest evidence and recommendations for SCS and PNS in chronic pain care.



NANS 2027

REGISTRATION & HOUSING NOW OPEN!

REGISTER TODAY →

The banner features a background image of the Caesars Palace building. Three circular inset images show: a woman speaking at a podium, a person in a surgical mask and cap, and a group of people sitting in an audience.

Neuromodulation Without Boundaries: A Conversation with the NANS 2027 Scientific Program Chairs

What happens when neuromodulation moves beyond traditional targets, technologies, and disciplines? For NANS 2027 Scientific Program Co-Chairs **Rushna Ali, MD**, and **Dalia Elmofty, MD**, it means bringing together ideas and expertise from across the field to explore where neuromodulation is headed next.



Rushna Ali, MD
NANS 2027 SPC
Co-Chair



Dalia Elmofty, MD
NANS 2027 SPC
Co-Chair

Under the theme *“Neuromodulation Without Boundaries: Innovations in the Era of Neural Networks & Interfaces,”* **NANS 2027** will span the continuum from preclinical science to clinical implementation while exploring emerging areas including artificial intelligence, brain-computer interfaces, network-based neuromodulation, closed-loop systems, and restorative therapies.

Q: What does this year’s theme, “Neuromodulation Without Boundaries,” mean to you, and how is it reflected in the program?

Dr. Elmofty: To me, “Neuromodulation Without Boundaries” reflects how our field is moving beyond traditional targets and technologies toward understanding and influencing neural networks. This year’s program brings together advances in SCS, DBS, PNS, brain-computer interfaces, AI, and closed-loop systems, with the goal of creating smarter, more personalized treatments for our patients.

Dr. Ali: It represents the ever-evolving world of neuromodulation, BCI, and data science, where collaboration is critical to progress. We see that in the interdisciplinary nature of the program, with science spanning the preclinical through post-implementation stages.

Q: What scientific or clinical developments are you most excited to see represented at NANS 2027?

Dr. Ali: BCI, network-based neuromodulation, and restorative therapies.

Dr. Elmofty: I’m especially excited about advances in closed-loop neuromodulation, AI, brain-computer interfaces, and more personalized approaches to stimulation. We’re also seeing neuromodulation expand into new targets and conditions, which really highlights how quickly the field is evolving.

Q: Where do you think attendees will see the “without boundaries” concept come to life most clearly in the program?

Dr. Ali: In the highly multidisciplinary nature of the sessions. They honor the past, describe the current state, and shed light on the future of the field.

Dr. Elmofty: I think the interactive panels, debates, and forward-looking sessions will really make NANS 2027 stand out. We’re tackling questions where the field is still evolving, bringing together different perspectives, and giving attendees the opportunity to be part of the conversation about where neuromodulation is headed next.

Continued on next page



Neuromodulation Without Boundaries, continued

Q: If you could describe NANS 2027 in one word, what would it be—and why?

Dr. Elmofty: Transformative. NANS 2027 highlights how neuromodulation is evolving—breaking traditional boundaries, embracing new technologies, and changing how we understand and interact with the nervous system.

Dr. Ali: Thought-provoking and inspiring. The program brings together perspectives from across the field and challenges us to think differently about where neuromodulation is headed.

Registration and housing are now open for [NANS 2027](#), January 21–24 at Caesars Palace in Las Vegas. [Secure your spot](#) and [explore the NANS 2027 program](#) to start planning your meeting experience.



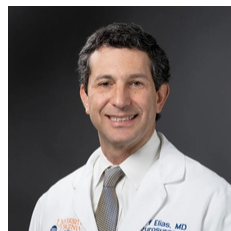
The Expanding Role of Focused Ultrasound in Movement Disorders

Focused ultrasound (FUS) has quickly become one of the most influential treatment platforms in functional neurosurgery. It is helpful to think of FUS in two broad categories: high-intensity

focused ultrasound (HIFU), which delivers enough acoustic energy to create a permanent thermal lesion, and low-intensity focused ultrasound (LIFU), which operates below the ablative threshold and offers the possibility of reversible, noninvasive neuromodulation as well as transient blood–brain barrier (BBB) opening for targeted drug and biologic delivery. The clinical story began with unilateral MR-guided FUS (MRgFUS) thalamotomy for medication-refractory essential tremor (ET) and has now broadened into Parkinson's disease (PD), FDA-approved staged bilateral procedures, dystonia targets, and early-stage neuromodulation trials.¹ The 2026 position-statement update from the American Society for Stereotactic and Functional Neurosurgery (ASSFN) synthesizes the evidence base that has driven this expansion.² Figure 1 summarizes the field's landmark milestones, and Figure 2 illustrates a representative MRgFUS treatment, from the treatment platform itself to the resulting thalamotomy lesion and the clinical change in tremor.



Divine C. Nwafor, MD, PhD
University of Virginia



W. Jeffrey Elias, MD
University of Virginia



Shayan Moosa, MD
University of Virginia

Continued on next page



Focused Ultrasound, *continued*

Landmark milestones in focused-ultrasound treatment of movement disorders (2013-2026)

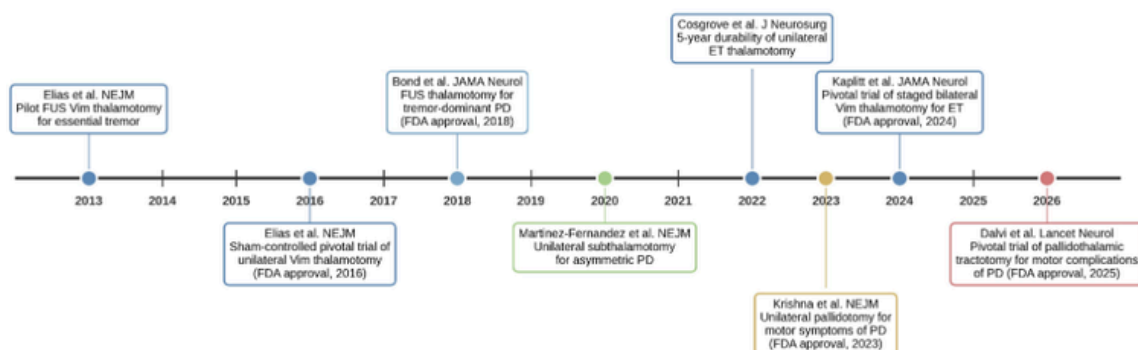


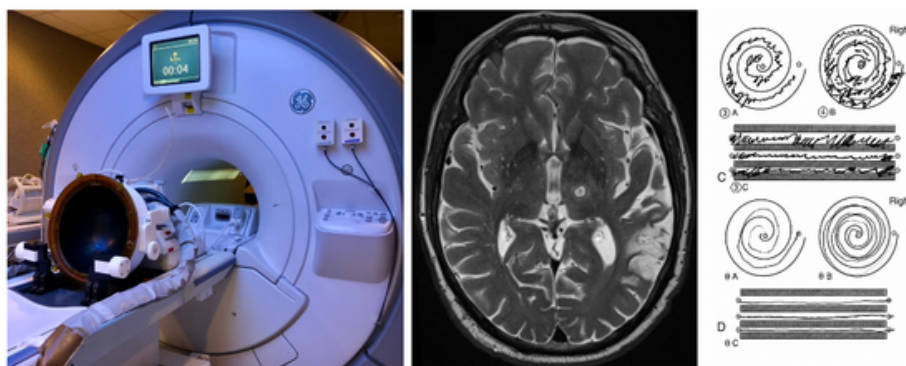
Figure 1. Landmark milestones in the clinical application of focused ultrasound for movement disorders, 2013–2026. The trajectory has moved from a first-in-human pilot for essential tremor to FDA-approved indications for tremor-dominant Parkinson's disease and for motor symptoms of Parkinson's disease, with staged bilateral procedures and dystonia targets now in early clinical use.

Figure 2. Clinical application of MRgFUS for movement disorders.

Left: the Insightec Exablate transducer docked to the MRI scanner.

Center: axial T2-weighted MRI demonstrating a left thalamotomy lesion.

Right: spiral drawings obtained preoperatively (top pane) and postoperatively (bottom pane).



Essential tremor: established evidence and long-term outcomes

The strongest evidence for MRgFUS remains in essential tremor. In the sham-controlled pivotal trial by Elias and colleagues, unilateral thalamotomy of the ventral intermediate nucleus (Vim) produced a 47% improvement in the hand-tremor score at three months versus no change in the sham arm, and the benefit was sustained at 12 months.³ The pilot data preceding that trial had already demonstrated feasibility and safety in a first-in-human cohort at the University of Virginia.⁴ Those findings were subsequently replicated at independent centers: Lipsman and colleagues reported a proof-of-concept series in Toronto,⁵ and Chang and colleagues confirmed comparable clinical and radiological outcomes in a separate cohort.⁶ Long-term follow-up has been reassuring:

Halpern and colleagues reported sustained tremor control at 3 years,⁷ and Cosgrove and colleagues extended that follow-up to 5 years with durable benefit and no new delayed adverse events.⁸ A pooled safety review by Fishman and colleagues found that serious adverse events across five MRgFUS trials occurred in only ~1.6% of treatments; most complications (gait disturbance, paresthesias, dysarthria) were mild-to-moderate and often improved by 12 months.⁹ The majority of these adverse effects are attributable to perilesional edema, which typically resolves within approximately three weeks; dysarthria is uncommon in unilateral treatments and is most often encountered in patients undergoing bilateral lesioning. These data support the ASSFN's 2026 position statement that MRgFUS lesioning is safe, effective, and durable for refractory ET in appropriately selected patients.²

Continued on next page



Parkinson's disease: emerging targets and indications

The range of FUS targets and indications in Parkinson's disease has expanded substantially in recent years. FUS thalamotomy has shown meaningful improvement in tremor-dominant PD (Bond et al., 2017, which led to FDA approval in 2018).¹⁰ Other lesion targets, which are similar to those used in deep brain stimulation, are addressing PD symptom clusters beyond tremor. In a sham-controlled trial by Martinez-Fernandez and colleagues, unilateral subthalamotomy in asymmetric PD improved the Movement Disorder Society–Unified Parkinson's Disease Rating Scale Part III (MDS-UPDRS III) off-medication motor score on the treated side by ~8.1 points more than sham, with meaningful gains in tremor and rigidity and a more modest signal for bradykinesia (not FDA-approved).¹¹ Krishna and colleagues subsequently reported a sham-controlled trial of unilateral pallidotomy for motor symptoms of PD, showing a response rate of 69% in the FUS arm versus 32% in the sham arm at three months, driven by improvements in dyskinesia and motor fluctuations, and leading to FDA approval in 2023.¹² Together, these studies suggest that FUS lesioning can be tailored to the dominant parkinsonian symptom profile: Vim for tremor, the globus pallidus internus (GPi) for dyskinesia and motor fluctuations, and potentially the subthalamic nucleus (STN) for tremor-plus-rigidity. The ASSFN update notes, however, that long-term durability in PD is less well established than in ET, with signals of tremor recurrence and modest long-term effects on non-tremor motor symptoms.²

Staged bilateral MRgFUS thalamotomy

Historically, bilateral lesioning in movement disorders raised understandable concern because of speech, gait, and cognitive side effects, which had defined

much of the earlier radiofrequency and gamma-knife experience. That picture is now changing. In 2024, Kaplitt and colleagues reported the pivotal open-label, multicenter trial of staged bilateral Vim thalamotomy in 51 ET patients (minimum 9 months between sides), showing a 62% reduction in Clinical Rating Scale for Tremor (CRST) Part A and B scores at 1 year, with 85% of adverse effects being mild and only a single severe event. Notably, the rate of speech-related deficits was higher than after unilateral thalamotomy: dysarthria was reported in 15 patients overall and persisted at 12 months in 7 of the 51 treated (~14%), all graded mild.¹³ Dysarthria was substantially less common in the 2016 pivotal unilateral sham-controlled trial, where it was transient and was not among the deficits persisting at 12 months; Kaplitt and colleagues note that their adverse-event profile was otherwise similar in frequency and severity to that unilateral experience, mild dysarthria being the exception.³ Those data supported the 2024 FDA approval of staged bilateral MRgFUS thalamotomy for ET.² Earlier work by Iorio-Morin and colleagues and other single-center series had already shown that tremor improvement on the second side approaches that of the first, including for axial tremor (head, voice).¹⁴ Staged bilateral pallidothalamic tractotomy for advanced PD has similarly shown broad efficacy across cardinal motor symptoms. In their single-center series, Gallay and colleagues reported a ~52% reduction in overall UPDRS Part III scores at 1 year (legacy UPDRS, not MDS-UPDRS), driven by substantial improvements in tremor (~91%), distal hypobradycinesia (~54%), distal rigidity (~67%), and pain (~89%), with complete suppression of dyskinesia in all four affected patients (4/4). These gains were offset by a ~58% increase in speech-related side effects, which remain the principal limitation and an important element of informed consent.¹⁵ Most recently, a prospective, multicenter, single-arm trial evaluated staged bilateral MRgFUS



Focused Ultrasound, *continued*

pallidothalamic tractotomy for motor complications of Parkinson's disease: 54 patients at nine centers underwent a unilateral procedure, and 40 proceeded to the second side, with follow-up to 12 months after bilateral treatment. Motor complications improved by 66.8% at 3 months after the second procedure, the proportion of patients experiencing dyskinesia fell substantially, and benefit was maintained through 12 months. The authors emphasize, however, that the incremental motor gain from the second side was small relative to a rise in persistent moderate-to-severe speech, gait, and balance events, and that bilateral treatment therefore demands rigorous patient selection and explicit counseling about cumulative risk.¹⁶ These data supported FDA clearance of staged bilateral pallidothalamic tractotomy in July 2025.¹⁶ Note that although the FDA has approved staged bilateral thalamotomy, current Centers for Medicare & Medicaid Services (CMS) coverage still excludes bilateral treatment, a discrepancy that matters for U.S. practice.²

Dystonia and other emerging indications

FUS is also beginning to reach movement disorders beyond tremor and classic PD. Early series in focal hand dystonia (musician's dystonia and writer's cramp) suggest that carefully targeted pallidothalamic or ventro-oral thalamic lesioning may produce meaningful symptomatic and functional improvement in select patients.¹⁷ The pallidothalamic-tract target discussed above was developed in advanced PD, where Galloway and colleagues' single-center consecutive series provided the original one-year outcome data, and the same target is now being applied to dystonia.¹⁸ Cerebellothalamic tractotomy has been proposed as an alternative target for chronic therapy-resistant tremor, with ~65% CRST improvement at one year in early work.¹⁹ Beyond movement disorders, FUS is being extended to other stereotactic indications, including mesencephalotomy for cancer-associated craniofacial

pain,²⁰ underscoring the broader trajectory of the platform in functional neurosurgery. These reports are still small and largely single-center, but they highlight a key theme: FUS is evolving from a single-procedure therapy into a platform technology with multiple potential targets and indications.

Future directions

Perhaps the most transformative near-term development is that the next frontier of FUS in movement disorders may not be lesioning at all. LIFU is being investigated as a way to modulate deep-brain circuits noninvasively and reversibly, and tremor has become the natural testing ground because the effect can be measured within minutes of sonication. In three patients with ET, Riis and colleagues applied brief 15-second Vim sonications at a 10% duty cycle, repeated fewer than 30 times over 90 minutes, and nearly abolished tremor in two of the three (97–98% reduction in tremor amplitude).²¹ Bancel and colleagues delivered MR-guided low-power stimulation to the Vim and dentatorubrothalamic tract and observed at least an 89% reduction in tremor power in five patients, sustained beyond 23 minutes in three, with no significant thermal rise on MR thermometry; four patients did not respond, underscoring how much of the parameter space remains unmapped.²² In an open-label office-based series, Deveney and colleagues treated the first 10 ET participants with eight 10-minute LIFU sessions targeted to the Vim, supporting feasibility and safety outside the MR suite.²³ Randomized sham-controlled crossover trials and systematic parameter-mapping studies are now under way. For patients who are not candidates for permanent lesioning—for example, those with milder disease, unclear best target, or a preference for reversible therapy—LIFU could offer a fundamentally different value proposition. In parallel, advances in imaging and targeting are progressively improving lesion precision, dose control, and the ability to spare

Continued on next page



Focused Ultrasound, *continued*

adjacent white-matter tracts, including fast gray-matter acquisition T1 inversion recovery (FGATIR) and white-matter-nulled sequences, diffusion tractography,²⁴ and emerging AI-assisted targeting workflows. A parallel LIFU application is transient, reversible opening of the BBB with intravenous microbubbles; Gasca-Salas and colleagues demonstrated the safety and feasibility of this approach in Parkinson's disease dementia, raising the prospect of targeted delivery of neurorestorative therapeutics to deep-brain structures.²⁵ Collectively, these advances position FUS to remain one of the most important growth areas at the intersection of imaging, engineering, and functional neurosurgery over the coming decade.

Practical clinical takeaways

Three practical themes for functional-neurosurgery practice:

1. Patient selection matters. FUS is not for every tremor or every Parkinson's phenotype. Skull density ratio (SDR; ≥ 0.40 for CMS coverage, ≥ 0.35 for FDA), cognitive baseline (Mini-Mental State Examination [MMSE] ≥ 24), medication-refractory tremor, and axial-symptom burden all matter and are explicit ASSFN and CMS criteria.
2. Target selection is key. Vim, GPi, and pallidothalamic-tract targets each address different symptom clusters. Choose the target based on the symptom you are trying to treat.
3. The benefit–side-effect tradeoff must be considered. Sensory paresthesias, mild gait ataxia, and dysarthria remain real, especially with bilateral or high-dose sonications. Multidisciplinary evaluation and long-term registry data are how the field will continue to refine outcomes.

Conclusion

HIFU lesioning is no longer limited to unilateral thalamotomy for essential tremor. It has expanded into FDA-approved staged bilateral thalamotomy for essential tremor and staged bilateral pallidotomy for Parkinson's disease, alongside investigational applications such as subthalamotomy for asymmetric Parkinson's disease, pallidothalamic tractotomy for dystonia targets, and, increasingly, noninvasive neuromodulation. As the ASSFN's 2026 position statement makes clear, the field now has both prospective randomized data and multi-year durability data to anchor its clinical use, while long-term durability in PD, the role of LIFU-based neuromodulation, and the ideal targeting strategy for dystonia remain open questions.² Because FUS sits at the intersection of imaging, engineering, and clinical decision-making, it will remain one of the most important growth areas in functional neurosurgery and neuromodulation over the coming decade.

References

1. Pouratian N, Baltuch G, Elias WJ, Gross R. American Society for Stereotactic and Functional Neurosurgery position statement on magnetic resonance-guided focused ultrasound for the management of essential tremor. *Neurosurgery*. 2020;87(2):E126–E129. doi:10.1093/neuros/nyz510. PMID: 31832649.
2. Hamani C, Elias WJ, Baltuch GH, et al. Magnetic resonance-guided focused ultrasound for the management of tremor: update on the position statement of the American Society for Stereotactic and Functional Neurosurgery. *J Neurosurg*. 2026;145(1):4–12. doi:10.3171/2025.11.JNS251828. PMID: 41894813.

Continued on next page



Focused Ultrasound, *continued*

3. Elias WJ, Lipsman N, Ondo WG, et al. A randomized trial of focused ultrasound thalamotomy for essential tremor. *N Engl J Med*. 2016;375(8):730–739. doi:10.1056/NEJMoa1600159. PMID: 27557301.
4. Elias WJ, Huss D, Voss T, et al. A pilot study of focused ultrasound thalamotomy for essential tremor. *N Engl J Med*. 2013;369(7):640–648. doi:10.1056/NEJMoa1300962. PMID: 23944301.
5. Lipsman N, Schwartz ML, Huang Y, et al. MR-guided focused ultrasound thalamotomy for essential tremor: a proof-of-concept study. *Lancet Neurol*. 2013;12(5):462–468. doi:10.1016/S1474-4422(13)70048-6.
6. Chang WS, Jung HH, Kweon EJ, Zadicario E, Rachmilevitch I, Chang JW. Unilateral magnetic resonance guided focused ultrasound thalamotomy for essential tremor: practices and clinicoradiological outcomes. *J Neurol Neurosurg Psychiatry*. 2015;86(3):257–264. doi:10.1136/jnnp-2014-307642. PMID: 24876191.
7. Halpern CH, Santini V, Lipsman N, et al. Three-year follow-up of prospective trial of focused ultrasound thalamotomy for essential tremor. *Neurology*. 2019;93(24):e2284–e2293. doi:10.1212/WNL.00000000000008561. PMID: 31748250.
8. Cosgrove GR, Lipsman N, Lozano AM, et al. Magnetic resonance imaging-guided focused ultrasound thalamotomy for essential tremor: 5-year follow-up results. *J Neurosurg*. 2023;138(4):1028–1033. doi:10.3171/2022.6.JNS212483. PMID: 35932269.
9. Fishman PS, Elias WJ, Ghanouni P, et al. Neurological adverse event profile of magnetic resonance imaging-guided focused ultrasound thalamotomy for essential tremor. *Mov Disord*. 2018;33(5):843–847. doi:10.1002/mds.27401. PMID: 29701263.
10. Bond AE, Shah BB, Huss DS, et al. Safety and efficacy of focused ultrasound thalamotomy for patients with medication-refractory, tremor-dominant Parkinson disease: a randomized clinical trial. *JAMA Neurol*. 2017;74(12):1412–1418. doi:10.1001/jamaneurol.2017.3098. PMID: 29084313.
11. Martinez-Fernandez R, Máñez-Miró JU, Rodriguez-Rojas R, et al. Randomized trial of focused ultrasound subthalamotomy for Parkinson's disease. *N Engl J Med*. 2020;383(26):2501–2513. doi:10.1056/NEJMoa2016311. PMID: 33369354.
12. Krishna V, Fishman PS, Eisenberg HM, et al. Trial of globus pallidus focused ultrasound ablation in Parkinson's disease. *N Engl J Med*. 2023;388(8):683–693. doi:10.1056/NEJMoa2202721. PMID: 36812432.
13. Kaplitt MG, Krishna V, Eisenberg HM, et al. Safety and efficacy of staged, bilateral focused ultrasound thalamotomy in essential tremor: an open-label clinical trial. *JAMA Neurol*. 2024;81(9):939–946. doi:10.1001/jamaneurol.2024.2295. PMID: 39073822.
14. Iorio-Morin C, Yamamoto K, Sarica C, et al. Bilateral focused ultrasound thalamotomy for essential tremor (BEST-FUS phase 2 trial). *Mov Disord*. 2021;36(11):2653–2662. doi:10.1002/mds.28716. PMID: 34288097.
15. Gallay MN, Moser D, Magara AE, Haufler F, Jeanmonod D. Bilateral MR-guided focused ultrasound pallidothalamic tractotomy for Parkinson's disease with 1-year follow-up. *Front Neurol*. 2021;12:601153. doi:10.3389/fneur.2021.601153. PMID: 33633664.

Continued on next page



Focused Ultrasound, continued

16. Dalvi A, Eisenberg HM, Wu P, Zucker L, Chang WC, Sarva H, Fishman PS, Buch VP, Matarazzo M, Del Alamo M, Rodriguez-Oroz MC, González-Quarante LH, Sani S, Ghanouni P, Patel N, Pourfar M, Mogilner A, Obeso JA, Kaplitt MG. 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. *Lancet Neurol.* 2026 Jul;25(7):654–663. doi:10.1016/S1474-4422(26)00142-0. PMID: 42309086.
17. Horisawa S, Yamaguchi T, Abe K, et al. Focused ultrasound thalamotomy for focal hand dystonia: a pilot study. *Mov Disord.* 2021;36(8):1955–1959. doi:10.1002/mds.28613. PMID: 34050695.
18. Gallay MN, Moser D, Rossi F, et al. MRgFUS pallidothalamic tractotomy for chronic therapy-resistant Parkinson's disease in 51 consecutive patients: single-center experience. *Front Surg.* 2019;6:76. doi:10.3389/fsurg.2019.00076. PMID: 31993437.
19. Gallay MN, Moser D, Jeanmonod D. MR-guided focused ultrasound cerebellothalamic tractotomy for chronic therapy-resistant essential tremor: anatomical target reappraisal and clinical results. *J Neurosurg.* 2021;134(2):376–385. doi:10.3171/2019.12.JNS192219. PMID: 32032945.
20. Elias WJ, Liu CC, Nwafor D, Finan PH, Quigg M, Moosa S. Stereotactic focused ultrasound mesencephalotomy for the treatment of head and neck cancer pain. *Stereotact Funct Neurosurg.* 2025. doi:10.1159/000547639. PMID: 40716439.
21. Riis TS, Losser AJ, Kassavetis P, Moretti P, Kubanek J. Noninvasive modulation of essential tremor with focused ultrasonic waves. *J Neural Eng.* 2024;21(1):016033. doi:10.1088/1741-2552/ad27ef. PMID: 38335553.
22. Bancel T, Béranger B, Daniel M, et al. Sustained reduction of essential tremor with low-power non-thermal transcranial focused ultrasound stimulations in humans. *Brain Stimul.* 2024;17(3):636–647. doi:10.1016/j.brs.2024.05.003. PMID: 38734066.
23. Deveney CM, Surya JR, Haroon JM, et al. Transcranial focused ultrasound for the treatment of tremor: a preliminary case series. *Brain Stimul.* 2024;17(1):35–38. doi:10.1016/j.brs.2023.12.007. PMID: 38128826.
24. Sammartino F, Krishna V, King NKK, et al. Tractography-based ventral intermediate nucleus targeting: novel methodology and intraoperative validation. *Mov Disord.* 2016;31(8):1217–1225. doi:10.1002/mds.26633. PMID: 27214406.
25. Gasca-Salas C, Fernández-Rodríguez B, Pineda-Pardo JA, et al. Blood-brain barrier opening with focused ultrasound in Parkinson's disease dementia. *Nat Commun.* 2021;12(1):779. doi:10.1038/s41467-021-21022-9. PMID: 33536430.

High-Intensity Focused Ultrasound Neuroablation: A Non-Invasive Advance Reshaping Management of Lumbar Facet-Mediated Pain

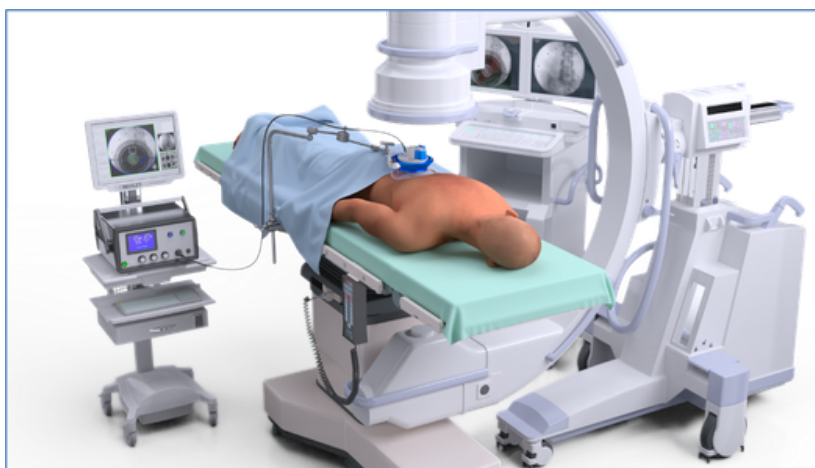


Ofer M. Wellisch, MD, MPH

Director, Pain Medicine; Stamford Health

Assistant Professor of Clinical Anesthesiology; Columbia University Vagelos College of Physicians and Surgeons

Chronic low back pain remains a leading driver of disability, lost productivity, and healthcare utilization. Lumbar zygapophyseal (facet) joint pain accounts for 15–40% of cases in interventional pain practices, with prevalence estimates of 10–29% in the broader mechanical low-back-pain population. For patients who fail conservative care, radiofrequency ablation (RFA) of the medial branch of the dorsal ramus has been the procedural standard for decades.



Yet, RFA is inherently invasive, requiring sterile technique, skin puncture, local anesthesia or sedation, and carrying risks of infection, bleeding, nerve injury, and post-procedural flare. Outcomes also vary with technical factors, patient selection, and operator experience.

High-intensity focused ultrasound (HIFU) represents a genuinely non-invasive alternative that is now poised to change the treatment paradigm. A portable, fluoroscopy-guided device (FUSMobile, Alpharetta, GA) focuses acoustic energy through a disposable gel pad to create a precise thermal lesion at the bone/soft-tissue interface where the medial branch nerve courses. No needles, anesthesia, or sterile draping are needed. Patients remain awake, communicate in real time, and typically leave the procedural suite or office within an hour.

Building the Evidence Base

Early clinical work established safety and feasibility. The 2022 first-in-human pilot study (Perez et al.) treated 10 participants with documented facet-mediated pain; all tolerated the procedure well, with no significant device or procedure-related adverse events and demonstrated clinically meaningful pain reduction comparable to historical RFA benchmarks. A larger prospective open-label multicenter study (Gofeld et al., 2024) enrolled 30 participants and demonstrated an 82.6% individual responder rate at six months (≥ 2 -point NRS reduction without increased opioid use, or opioid reduction without NRS worsening).

Continued on next page



Ultrasound Neuroablation, *continued*

Average NRS fell from 7.1 at baseline to 3.3 assessed at 180 days, with parallel improvements in Oswestry Disability Index, Brief Pain Inventory, and Patient Global Impression of Change. Optional post-procedure MRI confirmed targeted tissue changes at the intended sites.

These single-arm data set the stage for the pivotal multicenter randomized, double-blind, sham-controlled trial (NCT05154448) whose primary results are now under review for publication. Conducted at 10 U.S. sites under FDA IDE approval, the study randomized 80 participants (41 active HIFU, 39 sham) after a 10-patient roll-in phase. Eligible patients had chronic facet-mediated pain confirmed by dual medial branch blocks or prior successful RFA.

Relative safety was established with no serious or severe device or procedure-related adverse events in any arm, including crossovers. The study's primary efficacy endpoint was achieved and surpassed the required statistical significance. Subgroup and sensitivity analyses confirmed consistent benefit across age, sex, BMI, baseline pain, number of treated levels, and study sites.

A Broader Trend in Neuromodulation

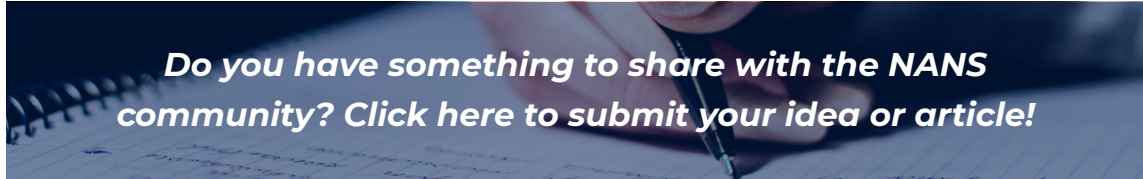
This development fits squarely within the larger evolution of neuromodulation toward less invasive, more precise, image-guided therapies. Just as spinal cord stimulation has progressed from paddle leads requiring laminectomy to percutaneous systems with closed-loop feedback and waveform innovation, and just as dorsal-root-ganglion and peripheral-nerve stimulation have refined anatomic targeting, HIFU brings focused-energy delivery to an indication long dominated by needle-based procedures.

The practical advantages are immediate. Additionally, patients on anticoagulation, those with higher procedural risk, or individuals simply averse to needles now have a viable option. Procedure time is reduced by approximately 30%, fluoroscopy exposure is modest, and post-procedure discomfort is minimal. The lesion created at the bone interface tends to be larger than conventional cooled or pulsed RFA lesions, potentially ablating a longer nerve segment and offering the prospect of more durable relief, though longer-term durability data are still needed.

From a health-systems perspective, the absence of sedation, sterile setup, and post-procedure monitoring requirements lowers resource utilization and expands the settings in which the procedure can be offered (e.g., an office setting). For a field facing reimbursement pressure, prior-authorization burden, and private-equity consolidation, a non-invasive, high-value intervention is timely.

Looking Ahead

The Neurolyser XR pivotal trial met its primary regulatory endpoint, and FDA De Novo marketing authorization was granted in late 2025. As with any new technology, real-world adoption will depend on appropriate patient selection, operator training, and integration into multimodal algorithms that combine procedural intervention with rehabilitation, behavioral strategies, and judicious pharmacotherapy.

A close-up image of a hand holding a pen, writing on a notepad. The text is overlaid on the image.

Do you have something to share with the NANS community? Click here to submit your idea or article!

Continued on next page



Ultrasound Neuroablation, *continued*

Future directions include longer-term durability studies and exploration of repeat-treatment intervals, as well as investigation of whether the larger lesion size translates into clinically meaningful differences in responder durability.

Pain medicine is not in retreat; it is recalibrating. The addition of a safe, effective, truly non-invasive option for one of the most common chronic pain conditions expands the therapeutic armamentarium and aligns with the specialty's trajectory toward patient-centered care. For the millions of Americans with refractory facet-mediated low back pain, HIFU offers a new chapter, one written without a needle.

References

1. Perez J, et al. Fluoroscopy-Guided High-Intensity Focused Ultrasound Neurotomy of the Lumbar Zygapophyseal Joints: A Clinical Pilot Study. *Pain Med.* 2022;23(1):67-75.
2. Gofeld M, et al. Fluoroscopy-guided high-intensity focused ultrasound neurotomy of the lumbar zygapophyseal joints: a prospective, open-label study. *Reg Anesth Pain Med.* 2025;50:464-470.
3. Kapural L, et al. High-Intensity Focused Ultrasound Ablation with the Neurolyser XR device... randomized, double-blinded, sham-controlled study. Manuscript under review.
4. Cohen SP, Raja SN. Pathogenesis, diagnosis, and treatment of lumbar zygapophysial (facet) joint pain. *Anesthesiology.* 2007;106(3):591-614.

President's Vision: Dr. Magda Anitescu



It is a great honor to serve as President of the North American Neuromodulation Society. I am grateful for the trust of our members and for the opportunity to help guide NANS during a period of remarkable transformation for our field.

Neuromodulation has changed the lives of countless patients and established itself as an essential component of modern medicine. Today, however, we stand at the beginning of

an even broader transformation. **Advances in artificial intelligence, bioelectronic medicine, brain-computer interfaces, neural sensing, focused ultrasound, and other emerging technologies are rapidly redefining how we understand, diagnose, and treat disorders of the nervous system.**

These developments present an extraordinary opportunity for our Society. While neuromodulation will always remain the foundation of NANS, I believe our future lies in embracing the broader neural interface ecosystem. Our vision is to create a multidisciplinary community where clinicians, neuroscientists, engineers, innovators, entrepreneurs, industry partners, and trainees come together to shape the future of our field and, most importantly, improve patient care.

Over the next several years, our strategic priorities will focus on expanding the reach, impact, and influence of NANS. We will broaden our membership to welcome new disciplines and perspectives that are driving innovation.

Continued on next page



President's Vision, *continued*

We will strengthen our commitment to scientific discovery by supporting collaborative research, developing research grant opportunities, and fostering partnerships that accelerate translation from the laboratory to clinical practice.

Equally important, we will continue to develop clinical practice guidelines, consensus statements, and scientific collaborations that position NANS as a leading source of knowledge, evidence, and innovation in neuromodulation and neural interface science. By bringing together multidisciplinary expertise and translating emerging evidence into meaningful clinical guidance, NANS can help establish standards that advance both the field and the quality of care we provide to our patients.

Advocacy will be an equally important component of this vision. Scientific innovation has limited impact if patients cannot access the therapies that can improve their lives. Therefore, our advocacy efforts must anticipate the future. As new neuromodulation and neural interface technologies move from research into clinical care, questions surrounding access, reimbursement, regulation, ethical implementation, and appropriate clinical standards will become increasingly important. NANS has an opportunity—and a responsibility—to bring scientific and clinical expertise to these discussions early, ensuring that policies affecting our field are informed by evidence, patient needs, and the perspectives of the clinicians, scientists, innovators, and entrepreneurs who understand these technologies best.

Education has always been one of our greatest strengths, and we will build upon that foundation. NANS must evolve from being known primarily for an outstanding annual meeting into a year-round educational organization. Through the development of NANS virtual educational programs, master classes, procedural training, digital learning, and interdisciplinary workshops, we will create continuous opportunities for learning, collaboration, mentorship, and professional growth.

Together, these efforts in science, education, advocacy, clinical guidance, innovation, and multidisciplinary collaboration will strengthen the role of NANS within the broader healthcare and scientific communities. They will also allow us to better serve our members—not only by providing education and scientific exchange, but by representing their expertise and the needs of their patients in the conversations that will determine the future of our field.

These initiatives are united by a single purpose: to position NANS as the leading multidisciplinary organization advancing neuromodulation and neural interface science through innovation, education, research, advocacy, and excellence in clinical care. This vision honors our remarkable history while preparing us for the opportunities that lie ahead.

Most importantly, this vision cannot be achieved by any one individual or committee. It will require the ideas, expertise, and engagement of our entire membership. I invite each of you to help shape the future of NANS as we work together to build a Society that not only responds to innovation but helps define it—and that ensures those innovations ultimately reach the patients who can benefit from them.

I look forward to this journey with all of you.

T7–T9 Spinal Cord Stimulation for Chronic Pelvic Pain Secondary to Pudendal Neuralgia After 35 Years of Symptoms: A Case Report

Kenneth Lam, BS; John Sealy School of Medicine, The University of Texas Medical Branch, Galveston, TX

Jai Ramesh, BS; John Sealy School of Medicine, The University of Texas Medical Branch, Galveston, TX

Amit Aggarwal, DO; Department of Anesthesiology, Duke University Health System, Durham, NC

Gulshan Doulatram, MD; Department of Anesthesiology, The University of Texas Medical Branch, Galveston, TX

Abstract

Background: Spinal cord stimulation (SCS) for pudendal neuralgia (PN) typically targets the T11–L1 region. This case describes a unique multi-site PN presentation successfully managed with a more rostral T7–T9 SCS configuration, adding a novel alternative for complex pain phenotypes to the literature.

Case Presentation: A 68-year-old woman presented with a 35-year history of refractory postpartum PN, reporting perineal and groin burning, right leg pain, and low back pain. After exhausting conservative therapies, nerve blocks and ablations, she underwent a successful SCS trial with leads at T9/T10, followed by permanent implantation at T7/T9 to achieve broader dermatomal coverage. At the 3-month follow-up, her average pain decreased from 5/10 to 2/10 with high-frequency stimulation, which significantly improved her ambulation and daily functioning. She continued to experience significant relief through nine months of follow-up.

Discussion: This patient presented a unique case given her 35-year symptom duration and the atypical expansion of pain beyond the classic pudendal distribution. Having exhausted conventional therapies, including ablations, she underwent permanent SCS implantation utilizing an unconventionally rostral target to address this broad pain footprint. By placing the right lead at T7 and the left at T9, rather than the standard T11–L1 location, we successfully captured the expanded lumbosacral pain while maintaining pelvic modulation.

Conclusion: Rostral SCS placement at T7 and T9 provides broader lumbosacral coverage than conventional targets. It represents a viable, effective intervention for patients with multifocal chronic pelvic pain secondary to PN when standard treatment options fail.

Introduction

Chronic pelvic pain (CPP) is a multifactorial syndrome characterized by pain lasting longer than six months that is perceived as originating from the pelvic region.¹ It is estimated to affect approximately 26% of the world's female population.¹ Management of this condition is challenging because multiple pain generators frequently coexist in the same patient.

Pudendal neuralgia (PN), a neuropathic cause of CPP, arises from irritation or entrapment of the nerve. The pelvic region is innervated by sympathetic,

parasympathetic, somatic, and splanchnic innervation originating from T12, L1, L2, S2, and S3.² PN presents as burning, tingling, or shooting pain that radiates in the perineal, genital, and gluteal distributions, with occasional radiation into the lower back from persistent nociceptive input from somatic structures and central sensitization.¹

Diagnosis of PN is largely clinical, guided by the Nantes criteria and diagnostic nerve blocks.^{3,4} However, diagnosis remains challenging due to the variability of

Continued on next page



T7–T9 Spinal Cord Stimulation, *continued*

symptoms present in this population. First-line management of PN typically includes conservative measures such as lifestyle modifications, pharmacotherapy (neuropathic agents, anti-inflammatories, muscle relaxants), and pelvic floor physical therapy.³ Pudendal nerve blocks can provide both diagnostic and therapeutic value. Other invasive procedures such as pulsed radiofrequency nerve ablations, implantable peripheral nerve stimulators, and surgical decompression are reserved for refractory cases. In such cases, spinal cord stimulation (SCS) is increasingly being investigated as a next-line option for refractory PN-mediated pelvic pain.⁵

Buffenoir et al. previously reported favorable outcomes with SCS targeting the conus medullaris in 27 consecutive PN patients, with leads placed at T11–L1.⁶ However, these patients presented following failed pudendal release surgery and demonstrated a classic pain distribution. We present a case of a patient with a 35-year history of refractory PN and a multi-site pain pattern who achieved relief with a more rostral lead configuration at T7–T9. Verbal consent was obtained from the patient for the publication of this case report. All identifying information has been removed or de-identified in accordance with HIPAA guidelines to protect patient privacy.

Case Presentation

A 68-year-old woman presented with a 35-year history of postpartum pudendal neuralgia characterized by chronic, intermittent burning and tingling pain originating from the perineum, groin, and between the buttocks, radiating to the right inner thigh and leg. She reported chronic urinary incontinence for the past 30 years and occasional low back, sacral, and coccygeal pain. Physical examination revealed no focal neurological deficits and a negative straight-leg raise but a positive FABER test, right sacroiliac joint tenderness, and bilateral gluteal and greater trochanteric tenderness. MRI of the lumbar spine revealed no

significant foraminal or central canal stenosis (Figure 1).

She had trialed extensive conservative management, including pregabalin, celecoxib, duloxetine, cyclobenzaprine, and physical therapy, with minimal relief. Subsequent interventions included L5–S1 interlaminar epidural steroid injections, right pudendal nerve blocks at the ischial spine near Alcock's canal (Figure 2), and conventional radiofrequency ablation of the right pudendal nerve, each providing only temporary relief. Given the chronicity and refractory nature of her symptoms, she was considered a candidate for spinal cord stimulation.

A trial with the left lead placed at T10 and the right lead at T9 produced a successful response (Figure 3). She subsequently proceeded with permanent implantation of a Nevro Omnia System (Omnia 16-contact IPG with Nevro 1058-70B 8-Contact, 70 cm leads), with the left lead positioned at the upper portion of T9 and the right lead at the middle portion of T7 (Figure 4).

At the 3-month follow-up, the patient reported a substantial reduction in pelvic pain. The average pain score improved from 5/10 pre-implantation, with episodes of 10/10 pain, to 2/10 post-implantation, with periods of complete relief. The patient also reported significant improvement in ambulation and daily functioning. Intermittent muscle spasms persisted, but the intensity improved with subsequent device parameter adjustments. At the 9-month follow-up, she continued to report significant relief from the stimulator.

Discussion

This case demonstrates that SCS with leads positioned at T7 and T9 can be an effective intervention for chronic pelvic pain secondary to pudendal neuralgia, even after more than three decades of disease progression. This configuration was selected to achieve broader stimulation coverage across the pelvic and lumbosacral dermatomes.

Continued on next page



T7–T9 Spinal Cord Stimulation, *continued*

Our patient's pain phenotype extended beyond the classic pudendal distribution to include sacroiliac joint pain, lower back pain, and bilateral gluteal and greater trochanteric tenderness, prompting consideration of a more rostral lead placement to capture a broader distribution. A similar strategy was described by Romero-Serrano and Esparza-Miñana in 2021, who placed leads at T8 and T9 to treat combined low back and pelvic pain following a pelvic fracture.⁷ Building on this precedent, the T7–T9 configuration was selected to extend coverage further while preserving modulation of S2–S4 pudendal symptoms. Our findings suggest that SCS at T7 and T9 may provide broader coverage of the pelvic and lumbosacral region while still effectively modulating symptoms within the S2–S4 distribution in appropriately selected patients.

This report is limited by its single-patient, retrospective design and by follow-up visits at three and nine months, leaving long-term durability of efficacy and generalizability unknown. Because this case was reviewed retrospectively, standardized outcome measures were not obtained before or after treatment.

Instead, the patient's response to treatment was gathered from clinical documentation and reported descriptively. Larger, prospective studies with longer follow-up are needed to define the optimal lead position, stimulation parameters, and durability of SCS for PN-related CPP.

Conclusion

This case demonstrates that T7–T9 spinal cord stimulation can be an effective intervention for chronic pelvic pain secondary to pudendal neuralgia. In this patient, more rostral lead placement offered broader pelvic and lumbosacral coverage than the conventional T11–L1 target while still adequately modulating S2–S4 pudendal symptoms. This approach may represent a viable alternative for patients with similar complex, multifocal presentations who have exhausted conventional interventional treatment options.

Larger studies are needed to define optimal long-term stimulation parameters in this population.

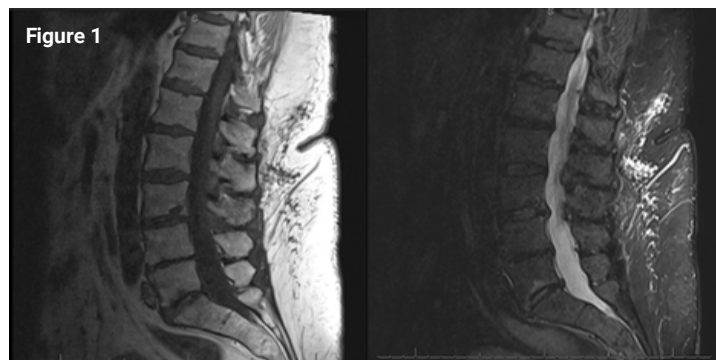


Figure 1. MRI Lumbar Spine Indicating Diffuse Mild Degenerative Changes with No Significant Spinal Canal Stenosis or High-Grade Neural Foraminal Narrowing at Any Level.

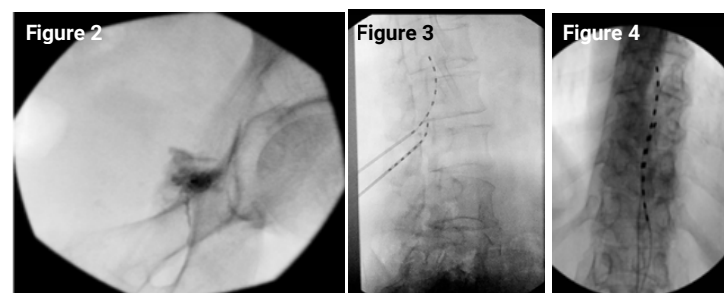


Figure 2. Right pudendal nerve block injection, located at the ischial spine near Alcock's canal.

Figure 3. Successful Response of Nevro SCS Trial Leads Placed at T9/T10

Figure 4. Permanent implantation of spinal cord stimulation leads, with the left lead positioned at T9 and the right lead at T7, selected to achieve broader stimulation coverage of the pelvic and lumbosacral dermatomes.

Author Contributions

KL and JR performed the literature review and drafted the manuscript. AA provided clinical care for the patient, contributed to the literature review, and revised the manuscript. GD provided clinical oversight and revised the manuscript.

Continued on next page



References

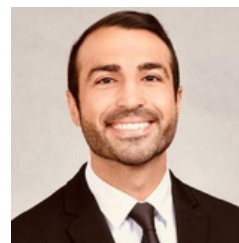
1. Lamvu G, Carrillo J, Ouyang C, Rapkin A. Chronic Pelvic Pain in Women: A Review. *JAMA*. 2021;325(23):2381-2391.
2. Levine AB, Parrent AG, MacDougall KW. Stimulation of the Spinal Cord and Dorsal Nerve Roots for Chronic Groin, Pelvic, and Abdominal Pain. *Pain Physician*. 2016 Jul;19(6):405-12. PMID: 27454271.
3. Ahmed M, Zavridis P, Hadjiconstanti D, Zis P. The Diagnosis and Management of Pudendal Neuralgia. *Pain Ther*. 2026;15(1):97-129. doi:10.1007/s40122-025-00803-w
4. Labat, J.-J., Riant, T., Robert, R., Amarenco, G., Lefaucheur, J.-P. and Rigaud, J. (2008), Diagnostic criteria for pudendal neuralgia by pudendal nerve entrapment (Nantes criteria)†. *Neurourol. Urodyn.*, 27: 306-310. <https://doi.org/10.1002/nau.20505>
5. Lam CM, Robinson CL, Kuester K, Tate JL, Patel K, Latif U. Minimally Invasive Interventional Management of Pudendal Neuralgia: A Narrative Review. *Curr Pain Headache Rep*. 2026;30(1):22.
6. Buffenoir K, Riout B, Hamel O, Labat JJ, Riant T, Robert R. Spinal cord stimulation of the conus medullaris for refractory pudendal neuralgia: a prospective study of 27 consecutive cases. *Neurourol Urodyn*. 2015;34(2):177-182.
7. Romero-Serrano E, Esparza-Miñana JM. Spinal cord stimulation in the approach to chronic pelvic pain: A case report and literature review. *Medicine (Baltimore)*. doi:2021;100(52):e28379.

Restoring Function Across the Neural Axis: A Vision for Multimodal Neuromodulation

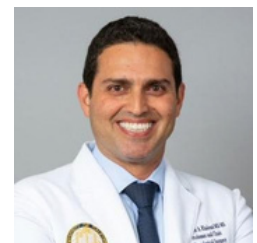
Neuromodulation is entering a new phase. For decades, the field has largely been organized around individual technologies, anatomical targets, or disease states: deep brain stimulation for movement disorders, spinal cord stimulation for pain, peripheral nerve stimulation for focal syndromes, vagus nerve stimulation for epilepsy, and more recently cortical and spinal stimulation strategies for motor recovery.

A patient recovering from stroke, spinal cord injury, traumatic brain injury, or peripheral nerve injury may simultaneously have impaired cortical output, disrupted descending pathways, maladaptive network activity, weakness, muscle atrophy, pain, spasticity, and loss of the sensory feedback required for normal movement. Treating only one component of this system may leave considerable recovery potential unrealized.

Our vision is to build a **multimodal restoration center** organized around a different question: rather than asking which neuromodulation technology a patient qualifies for, ask **what combination of interventions across the neural axis offers the greatest opportunity to restore meaningful function?**



Ronald Sahyouni, MD, PhD
Neurosurgery Chief Resident, UC San Diego



Alexander Khalessi, MD, MBA
Chair, Department of Neurological Surgery, UC San Diego

Continued on next page >

Restoring Function, *continued*

Treating the Neural Axis as a System

The nervous system is inherently distributed. Restoration should be approached the same way.

At the cortical level, noninvasive modalities such as navigated transcranial magnetic stimulation can be used to map residual motor networks, identify potential therapeutic targets, and modulate cortical excitability. Emerging invasive cortical interfaces may ultimately provide more precise recording and stimulation while enabling brain-computer interfaces capable of decoding movement intent.

At the spinal level, epidural and transcutaneous spinal cord stimulation are demonstrating the ability to increase the excitability of residual motor circuitry and, in selected patients, facilitate voluntary movement. Rather than viewing these technologies as isolated therapies, they can be considered another component of a larger restorative system.

Peripheral nerves offer an additional and particularly compelling interface. Functional electrical stimulation can activate muscles, but direct peripheral nerve interfaces may provide access to multiple muscles through a relatively small number of neural targets. These interfaces can potentially restore movement, provide sensory feedback, modulate pain, and reinforce activity-dependent plasticity.

At the level of muscle itself, electrical stimulation can preserve the substrate required for recovery. Maintaining muscle bulk, joint mobility, cardiovascular conditioning, and neuromuscular health is not simply supportive care.

If neural function is restored months or years later, the peripheral apparatus must still be capable of executing the recovered command. The result is a continuum extending from **cortex to spinal cord to peripheral nerve to muscle**, with rehabilitation connecting every level.

Rehabilitation as the Unifying Therapy

The most important component of this model may not be stimulation alone, but the way stimulation is paired with behavior.

Neuromodulation can alter the state of the nervous system, but rehabilitation provides the activity that tells the nervous system what to learn. The emerging opportunity is therefore to deliver stimulation precisely when a patient attempts or successfully performs a desired movement.

This concept is already visible in therapies that pair vagus nerve stimulation with upper-extremity rehabilitation after stroke. Similar principles may eventually extend to cortical stimulation, spinal stimulation, peripheral nerve stimulation, functional electrical stimulation, and combinations of these approaches.

In such a center, a patient might undergo detailed motor and neurophysiological phenotyping followed by a coordinated treatment program. Cortical stimulation could increase the excitability of residual motor networks. Spinal stimulation could facilitate descending signals. A peripheral nerve interface could amplify weak voluntary commands into functional movement. Muscle stimulation could maintain strength and conditioning. Intensive rehabilitation would then repeatedly pair the patient's intent with successful movement and sensory feedback.

The objective is not simply to compensate for neurological injury. It is to create the physiological conditions in which **restoration and neuroplasticity become more likely**.

Continued on next page 

Restoring Function, *continued*

From Device-Based Care to Restoration-Based Care

Building this model requires a different clinical infrastructure.

I envision a multidisciplinary restoration program bringing together neurosurgery, neurology, physical medicine and rehabilitation, neuropsychology, physical and occupational therapy, speech therapy, biomedical engineering, neurophysiology, and rehabilitation science.

Patients would undergo structured evaluation incorporating neurological examination, quantitative motor testing, electrophysiology, motion analysis, and when appropriate advanced imaging and connectomics. Their cases could then be reviewed in a multidisciplinary Functional Restoration Board, analogous to the tumor board model that has transformed multidisciplinary cancer care.

Instead of discussing resection margins and adjuvant therapy, the group would ask: Where is the functional pathway disrupted? What circuitry remains intact? Which neural targets are accessible? What technologies could be combined? What rehabilitation strategy should accompany them? How will recovery be objectively measured?

This framework also creates an ideal environment for clinical trials. Patients evaluated within a standardized restoration pathway could be matched to studies involving cortical stimulation, spinal stimulation, peripheral nerve interfaces, brain-computer interfaces, robotics, pharmacologic augmentation, or other emerging therapies.

The Next Frontier for Neuromodulation

The future of neuromodulation may therefore be less about identifying a single superior stimulation target and more about understanding how multiple targets interact.

A cortical interface may decode intent but still require an effective means of producing movement. Spinal stimulation may facilitate residual pathways but depend on cortical engagement and rehabilitation. Peripheral nerve stimulation may generate powerful movement but become considerably more meaningful when driven by the patient's own neural activity. Rehabilitation may become more effective when paired with precisely timed modulation of the circuits being trained.

These approaches should not necessarily compete with one another. They may ultimately be complementary components of a closed-loop restorative system.

Neuromodulation has already demonstrated that electrical interfaces can profoundly alter neural function. The challenge for the coming decade is to translate that capability into durable improvements in how patients **move, communicate, interact with their environment, and live independently.**

For our field, this represents an extraordinary opportunity. We can move from treating symptoms at individual anatomical targets toward engineering recovery across the nervous system.

The ultimate goal of a multimodal restoration center is simple: **identify every remaining biological pathway capable of contributing to function, strengthen those pathways, bridge those that cannot recover on their own, and give patients the greatest possible opportunity to regain meaningful independence.**