

Background

Neuromodulation, traditionally used in pain management, is now being explored for treating various non-painful conditions. Advancements have expanded its application to heart failure, renal failure, spinal cord injuries, overactive bladder syndrome, and cognitive impairment in neurodegenerative diseases.

Materials and Methods

This narrative review synthesizes current research on neuromodulation techniques, including dorsal root ganglion stimulation, sacral neurostimulation, and deep brain stimulation, evaluating their potential benefits and mechanisms in non-painful conditions.

HIGHLIGHTS

Heart & Renal Failure
Dorsal Root Ganglion Stimulation:
Induces diuresis in diuretic-resistant patients.

Spinal Cord Injuries & Paralysis
Epidural Stimulation & Brain-Spine Interface:
Restores motor function and enhances mobility.

Overactive Bladder Syndrome
Sacral & Tibial Nerve Stimulation:
Improves urinary continence and reduces symptoms.

Cognitive Impairment in Neurodegenerative Diseases
Deep Brain & Transcranial Magnetic Stimulation:
Enhances cognitive and motor functions in neurodegenerative diseases e.g. Parkinson's and Alzheimers

Table I: Summary of Neuromodulation Techniques and Their Applications Beyond Treating Pain Conditions

Condition	Neuromodulation Technique	Potential Benefits	Complications
Heart Failure & Renal Failure	Dorsal Root Ganglion Stimulation	Induces diuresis in diuretic-resistant patients (14)	Renal damage, effectiveness reduced in severe kidney damage (14)
Spinal Cord Injuries	Epidural Spinal Cord Stimulation, Brain-Spine Interface	Restores motor function, enhances mobility, improves sexuality (16, 23-30)	Device-related issues, biologic complications, damage to residual tissue (23, 31-33)
Overactive Bladder Syndrome	Sacral Neurostimulation, Tibial Nerve Stimulation	Improves urinary continence, reduces symptoms (40-43, 45-48, 54-58)	Pain, cost, lead migration, infection (42, 44, 47)
Cognitive Impairment in Neurodegenerative Diseases (PD, AD)	Deep Brain Stimulation, Transcranial Magnetic Stimulation	Enhances cognitive functions, motor functions, and improves the quality of life (60-67, 70-73, 76–84)	Discomfort, mixed efficacy, need for precise targeting (69, 86)

Results

Neuromodulation shows significant promise in several areas:

- Heart and Renal Failure: Dorsal root ganglion stimulation induces diuresis in diuretic-resistant patients, addressing fluid overload where traditional therapies fail.
- Spinal Cord Injuries: Epidural spinal cord stimulation and brain-spine interfaces facilitate motor function restoration, improving mobility and quality of life in paralyzed patients.
- Overactive Bladder Syndrome: Sacral neurostimulation and tibial nerve stimulation improve urinary continence and reduce symptoms, offering hope for patients unresponsive to conventional treatments.
- Cognitive Impairment in Neurodegenerative Diseases: Deep brain stimulation and transcranial magnetic stimulation enhance cognitive and motor functions in conditions like Parkinson's and Alzheimer's.

Conclusions

Neuromodulation is expanding beyond pain management, showing potential in treating various non-painful conditions. Continued research is essential to refine these techniques and optimize therapeutic protocols.

References

P. Chodakowski *et al.*, "Electrical Diuretics: Dorsal Root Ganglion Stimulation to Increase Diuresis," *Neuromodulation Technol. Neural Interface*, p. S1094715924000291, Feb. 2024, doi: 10.1016/j.neurom.2023.12.006.

M. E. Abraham *et al.*, "Utilizing Neuromodulation in the Treatment of Spinal Cord Injury: An Assessment of Clinical Trials from the National ClinicalTrials.gov Database," *World Neurosurg.*, vol. 177, pp. e361–e367, Sep. 2023, doi: 10.1016/j.wneu.2023.06.050.

W. Song, A. Amer, D. Ryan, and J. H. Martin, "Combined motor cortex and spinal cord neuromodulation promotes corticospinal system functional and structural plasticity and motor function after injury," *Exp. Neurol.*, vol. 277, pp. 46–57, Mar. 2016, doi: 10.1016/j.expneurol.2015.12.008.

J. W. Squair, A. Bierkefors, J. T. Inglis, T. Lam, and M. G. Carpenter, "Cortical and vestibular stimulation reveal preserved descending motor pathways in individuals with motor-complete spinal cord injury," *J. Rehabil. Med.*, vol. 48, no. 7, pp. 589–596, Jul. 2016, doi: 10.2340/16501977-2101.

R. Herman, J. He, S. D'Luzansky, W. Willis, and S. Dilli, "Spinal cord stimulation facilitates functional walking in a chronic, incomplete spinal cord injured," *Spinal Cord*, vol. 40, no. 2, pp. 65–68, Feb. 2002, doi: 10.1038/sc.3101263.

M. R. Carhart, Jiping He, R. Herman, S. D'Luzansky, and W. T. Willis, "Epidural spinal-cord stimulation facilitates recovery of functional walking following incomplete spinal-cord injury," *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 12, no. 1, pp. 32–42, Mar. 2004, doi: 10.1109/TNSRE.2003.822763.

H. Lorach *et al.*, "Walking naturally after spinal cord injury using a brain–spine interface," *Nature*, vol. 618, no. 7963, pp. 126–133, Jun. 2023, doi: 10.1038/s41586-023-06094-5.

A. A. Phillips and A. V. Krassioukov, "Contemporary Cardiovascular Concerns after Spinal Cord Injury: Mechanisms, Maladaptations, and Management," *J. Neurotrauma*, vol. 32, no. 24, pp. 1927–1942, Dec. 2015, doi: 10.1089/neu.2015.3903.

E. Pereira and A. Freen, "Autonomic neurosurgery: from microvascular decompression to image guided stimulation," *Biomed. Imaging Interv. J.*, vol. 3, no. 1, Jan. 2007, doi: 10.2349/biji.3.1.e14.

A. Chari, I. Hentall, M. Papadopoulos, and E. Pereira, "Surgical Neurostimulation for Spinal Cord Injury," *Brain Sci.*, vol. 7, no. 2, p. 18, Feb. 2017, doi: 10.3390/brainsci7020018.

K. Kumar *et al.*, "Spinal cord stimulation versus conventional medical management for neuropathic pain: A multicentre randomised controlled trial in patients with failed back surgery syndrome," *Pain*, vol. 132, no. 1, pp. 179–188, Nov. 2007, doi: 10.1016/j.pain.2007.07.028.

T. Cameron, "Safety and efficacy of spinal cord stimulation for the treatment of chronic pain: a 20-year literature review," *J. Neurosurg.*, vol. 100, no. 3 Suppl Spine, pp. 254–267, Mar. 2004, doi: 10.3171/spi.2004.100.3.0254.

J. Groothuis, N. F. Ramsey, G. M. J. Ramakers, and G. van der Plassse, "Physiological challenges for intracortical electrodes," *Brain Stimulat.*, vol. 7, no. 1, pp. 1–6, 2014, doi: 10.1016/j.brs.2013.07.001, [40].

C. L. Amundsen, A. A. Romero, M. G. Jamison, and G. D. Webster, "Sacral neuromodulation for intractable urge incontinence: Are there factors associated with cure?," *Urology*, vol. 66, no. 4, pp. 746–750, Oct. 2005, doi: 10.1016/j.urology.2005.04.031.

E. A. Tanagho and R. A. Schmidt, "Electrical Stimulation in the Clinical Management of the Neurogenic Bladder," *J. Urol.*, vol. 140, no. 6, pp. 1331–1339, Dec. 1988, doi: 10.1016/S0022-5347(17)42038-6.

T. Sukhu, M. Kennelly, and R. Kurpad, "Sacral neuromodulation in overactive bladder: a review and current perspectives," *Res. Rep. Urol.*, vol. Volume 8, pp. 193–199, Oct. 2016, doi: 10.2147/RRU.S89544.

J. Bartley, J. Gilleran, and K. Peters, "Neuromodulation for overactive bladder," *Nat. Rev. Urol.*, vol. 10, no. 9, pp. 513–521, Sep. 2013, doi: 10.1038/nrurol.2013.143.

S. W. Siegel *et al.*, "Long-term results of a multicenter study on sacral nerve stimulation for treatment of urinary urge incontinence, urgency-frequency, and retention," *Urology*, vol. 56, no. 6, pp. 87–91, Dec. 2000, doi: 10.1016/S0090-4295(00)00597-5.

A. Smith, D. Bevan, H. R. Douglas, and D. James, "Management of urinary incontinence in women: summary of updated NICE guidance," *BMJ*, vol. 347, p. f5170, Sep. 2013, doi: 10.1136/bmj.f5170.

G. Gaziev *et al.*, "Percutaneous Tibial Nerve Stimulation (PTNS) efficacy in the treatment of lower urinary tract dysfunctions: a systematic review," *BMC Urol.*, vol. 13, p. 61, Nov. 2013, doi: 10.1186/1471-2490-13-61.