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DEEP BRAIN STIMULATION IMPLEMENTATIONS OUTSIDE OF PARKINSON DISEASE, LITERATURE OVERVIEW AND FUTURE PROSPECTS

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ABSTRACT

Introduction: Since the introduction of deep brain stimulation (DBS) around 200 thousands of patients have been treated, with many proposed mechanisms such as enforcing electrical patterns, changes in neurotransmitters status and reversible inhibition of certain neural tracts. Since its key role in late stages of Parkinson disease, its success is being on the scope of being reproduced for the new ways to implement DBS to better patients' lives in various neurological disorders. With the high cost being its limitation and ability to correct or discontinue one of advantages, establishing new indications is going to improve quality of this procedure.
Aim of the study: This review focused on establishing evidence based knowledge about DBS utility in treating conditions outside of Parkinson disease spectrum and potential fields where data is yet required to obtain.
Methods and materials: Researchers searched MEDLINE and SCOPUS databases for articles from past 5 years. Phrases : " deep brain stimulation" "DBS" were used and work that focused purely on Parkinson disease was excluded. Proper studies were selected and presented in this review.
Conclusion: The convincing evidence was found to support the use of Deep brain stimulation in essential tremor, chronic pain, epilepsy, dystonia and obsessive compulsive disorder. The evidence supporting efficacy in Depression is only based on open label studies, with insufficient effort to prove it in blinded RCTs. The addiction indication is promising, however higher quality studies need to be obtained. DBS as treatment of Alzheimer is forming based on animal research and weak evidence only envisioning structural changes and singular evidence of patients improving, but without finding, at its current shape, clinical efficacy in meta-analysis or RCTs.

KEYWORDS

Deep Brain Stimulation, DBS, Alzheimer Disease, Obsessive Compulsive Disorder

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1.Introduction

The story of Deep brain stimulation (DBS) starts in treatment of tremor in the 80s. The cases of subthalamic nucleus deep brain stimuli in Parkinson diseases dates back to the 1990s and subsequently expands within years to treat other neurological disorders. It is estimated that DBS has been received now by 200 thousand patients. (Cavallieri et al., 2024) Stereotactic surgery allows placement of electrodes in subcortical nuclei or bundles of brain. It is suggested that the DBS "hijacks" improper neuronal circuits by reprograming its electrical activity to enforced frequency. Such action may result in deafferentation of neurons and inhibiting them. On cellular level it decreases body of neuron firing activity and increases axon action potential frequency. Moreover some impact on astrocytes is also hypothesized. It then provokes changes in substantial monoamines of brain: dopamine, serotonin, and noradrenaline. In long term, synaptic plasticity, epigenetic changes and neuroprotection of DBS is believed to play key role.(Jakobs et al., 2019) American study that analysed DBS implementation for period of 12 years (2010-2021) among United states population involved 1158 patients with 427 non-Parkinson implementation, the leading cause being essential tremor and only 5 procedures provided for patients with obsessive compulsive disorder.(Sedrak et al., 2025) The complications occurrence investigated in this publication, at all DBS placement methods showed the 3-year all cause reoperation chance being 18.1% and mortality rate 9.3% at 5 years, which requires mention of median age at the time of initial implant being 67 years IQR=59-72.(Sedrak et al., 2025) Opportunities brought by deep brain stimulation prompt the question of less common indications for DBS, theirs efficacy and other not yet established treatments. Unfortunately its cost and fear of invasive neurosurgical procedure often requires DBS to be introduced as last choice in refractory disease and toughens the way for the researchers to produce well obtained evidence.

The aim of the review

This review focused on establishing evidence based knowledge about DBS utility in treating conditions outside of Parkinson disease spectrum and potential fields where data is yet required to obtain.

Methods

Researchers searched MEDLINE and SCOPUS databases for articles from past 5 years. Phrases: " deep brain stimulation" "DBS" were used and work that focused purely on Parkinson disease was excluded. Proper studies were selected and presented in this review.

2.Neurological disorders

Essential tremor

It is most prevalent movement disorder, However deep brain stimulation for essential tremor was approved by FDA in 1997 this topic is yet studied.(Boogers et al., 2023; Cavallieri et al., 2024; Shih, 2025) With ventral intermediate nucleus of the thalamus (VIM-DBS) being well established target, but posterior subthalamic area (PSA) found non-inferior with indication for better short term effect, 80-90 % reduction in tremor amplitude is observed with those thalamic placements. Increasing power, often needed in late stages of disease to manage symptoms may induce Dysarthria, sensory disturbances, or stimulation induced ataxia.(Boogers et al., 2023; Bosch et al., 2025; Kondapavulur et al., 2022; Shih, 2025) which could be resolved by using biphasic instead of cathodic electrodes(Boogers et al., 2023). But as to nonmotor symptoms, the 2025 study concluded that there are no large neuropsychological changes alongside DBS treatment, though finding statistically significant but not of clinical significance improvement in depression and worsening in language and memory scores.(Bishay et al., 2025)

Chronic pain

The effectiveness of Deep brain stimulation in treating chronic pain lies in motor cortex stimulation (MCS). Studies targeting various brain regions demonstrate its efficacy in conditions such as phantom limb pain, stump pain, failed back surgery syndrome, anaesthesia

dolorosa, and burning hyperesthesia(Al-Husinat et al., 2025) The 2023 meta-analysis involving 966 patients marked statistically significant improvement, being pain reduction SMD=1.65 CI (1.31-2.0) in chronic pain indications (340 patients) such as posttraumatic neuropathic pain, but with the strongest evidence in non-RCT subgroup studies and high CI interval on RCT only subgroup. The largest proven size effect shown by ventral posterior lateral thalamic (VPL) (Shaheen et al., 2023) The 2025 study proved safety of using both anterior cingulate and thalamic DBS in treatment of chronic refractory neuropathic pain on 8 patients, and observed statistically significant improvement at EQ-5D utility index, however with no evidence on change in VAS.(Fontaine et al., 2025)

Epilepsy

Approximately 30% of patients with epilepsy are unable to achieve seizure control despite using at least two anti-seizure medications, The quick short term effect may be associated with microlesion effect (manipulation of brain tissue during surgery) The long term effects may be achieved by neurostimulation, (Asadi-Pooya et al., 2023; Bahadori et al., 2024) The anterior nucleus of thalamus deep brain stimulation (ANT-DBS) has been approved by the FDA for epilepsy treatment. The study from 2025 involving 40 patients highlights 56.7% ($p<0.001$) reduction in monthly seizure frequency with use of ANT-DBS, 5 patients (12.5%) became seizure free for at least 6 months. 25 patients 62.5% were considered to be responsive to treatment with highest rate in first 24 months.(Hu et al., 2025) Another study showed on group of 22 patients similar efficacy of ATN-DBS and Hippocampal deep brain stimulation Hip-DBS at disabling seizure reduction, 73,05 % 76.76% respectively, also finding no cognitive decline among patients treated with each DBS method.(Kim et al., 2025) 2024 metanalysis only adds to those findings among 999 included patients major decrease in the mean seizure frequency SMD: 0.609, 95% CI: 0.519 to 0.700, p-value < 0.001 with increase in QoL (Quality of live) SMD: -0.442, 95% CI: -0.576 to -0.308, p-value < 0.001. As to side effects the same study reports 12.7% of infection rate comparing to Parkinson's 9.9 % and singular cases of dysphagia and dyskinesia, not significant subdural hematomas and lead misplacement, managed by subsequent surgical intervention.(Bahadori et al., 2024)

Dystonia

Deep brain stimulation is well established in dystonia, its common target is globus pallidus internus (GPi-DBS), 2024 meta-analysis found decrease in BFMDRS-movement (best 0-120 worst) score after DBS for generalized dystonia SMD= -25.96 95%CI: -29.24 - -22.69, $p < 0.00001$ I^2=51%,(moderate heterogeneity) $p = 0.002$. and BFMDRS-disability -5.69 (95%CI: -7.04 - -4.35, $p < 0.00001$) with similar heterogeneity (Zoghdan et al., 2024). A 2025 retrospective study aimed to further optimize DBS for dystonia, with 38 patients enrolled it suggest the best spots for GPi-DBS as posterior ventral medial GPi, and for subthalamic nucleus (STN-DBS) its dorsolateral part. (Xue et al., 2025)

3.Psychiatric disorders

Obsessive compulsive disorder

Findings suggest that around 10% of OCD cases may be resistant to pharmacological treatment, The deep brain stimulation could be beneficial for those patients. Mechanism of action is combined effects of inhibition, excitation, informational lesion, and synchronized inhibition of neural cells and tracts, masking the intrinsic activity. The best prediction for success of DBS is decreased prefrontal cortex metabolism (Shea et al., 2025). The 2025 metanalysis highlights significant improvement among 323 patients subjected to deep brain stimulation Y-BOCS scale (0-40) (MD = 14.12 95 %CI = 12.43, 15.82, $p < 0.00001$, $I^2 = 73$ %) or 97 with HAM-A (0-56) scale MD = 10.71, 95 %CI = 8.55, 12.88, $p < 0.00001$, $I^2 = 63$ %) with no target of DBS (ALIC, anterior limb of internal capsule; NA, nucleus accumbens; BNST, bednucleus of stria terminalis; VC/VS, ventral capsule/ventral striatum; STN, sub-thalamic nucleus; ITP, inferior thalamic peduncle; MD/VA; medial dorsal and ventral anterior nucleus of thalamus; showing statistically significant superiority among Y-BOCS or HAM-A scales (Abdulbaki et al., 2025)

Addiction

Nucleus accumbens is often described as strongly involved in addiction mechanism, that led researchers to test deep brain stimulation as possible treatment for refractory disease. The 2025 study subjected 20 patients that failed previous standard treatments to nucleus accumbens Deep brain stimulation NAc-DBS and obtained more than 5 year abstinence in 10 out of 20 patients. However study lacked control group and selection bias or heterogeneity of patients may have played role in final outcomes. (Ge et al., 2025) Another study investigated matter of alcohol addiction, it yielded no statistically significant primary outcomes, however small study group of 12 patients still exhibited some differences in secondary outcomes such as significantly higher amount of abstention days on group with longer DBS use, and lower mean alcohol intake. Which suggest potential and poses the indication for further research. (Bach et al., 2023)

Depression

The RCT involving 35 participants, did not show statistically significant improvement in blinded phase but achieved 73.1% response in 24 months post implantation at open label part and DBS effectiveness is yet to be proved in blinded study with (Giacobbe et al., 2025) The 2025 study evaluated affective bias task as better in showing improvement along the course of DBS stimulation allowing for constant mood assessment. Which may be better tool to assess its influence. (Cui et al., 2025)

Alzheimer's disease

The 2023 meta-analysis found no statistical significance on cognitive outcomes of Alzheimer disease (AD) patients 0.145 = SMD, 95%CI, −0.246 to 0.537, $p = 0.467$; but claims high heterogeneity of this implantation method which prompts researchers to discovery of better way to implement DBS.(Majdi et al., 2023) The rat studies that use artificially impaired animals suggest mechanisms like disrupted hippocampal network synchronization in advanced AD as place for DBS supposed acting or regions such as medial forebrain bundle that was proved to play a key role in improving spatial memory in rats. (Riberas-Sánchez et al., 2024; Trevisiol et al., 2025) Another study, focused on Alzheimer associated decrease in hippocampal low frequency extracellular activity and Phase amplitude coupling (PAC). Proving then on animal model that those parameters may be corrected by DBS however with no certainty on clinical effect(Trevisiol et al., 2025) One study form 2025 brings evidence of 6 human implementation cases, it emphases that fornix DBS slows hippocampal atrophy, improves its volume and present case of one patient whose cognitive impairment improved during the period of DBS (Sankar et al., 2015) which prompts the question addressing ability of reversing the disease (in some patients) that was believed to be irreversible, but for now such intervention remains among singular reports rather than well proven evidence.

4.Conclusions

Deep brain stimulation is proving itself in neurological disorders among the world, with ones well established as essential tremor, dystonia or epilepsy to those yet being discovered, improved or hypothesized. Surely not yet popular OCD, depression or addiction treatment with promising effects among studies indicate future more common use in field of psychiatry. Not obvious indication but well-proven for DBS implementation is Chronic Pain, in the age of various pain-killers and patients whose suffering is still not alleviated it poses an alternative and is proven to be effective. Finally, there is no clinical evidence to support use of DBS in Alzheimer treatment, the changes in brain activity, and structure reported in experimental research may bring better established solution for brain stimulation in Alzheimer's. However there is a proper evidence to recommend deep brain stimulation for patients suffering from previously mentioned essential tremor, dystonia, epilepsy and previously mentioned cases of chronic pain among field of neurology. As to field of psychiatry Deep brain stimulation has reported crucial effects for those patients resistant to pharmacological treatment. Furthermore studies support use of DBS devices among patients with depression however without acquiring statistical significance among blinded trials. Finally current knowledge among DBS in refractory alcohol dependency encourages patients recruitment for another experimental studies to establish properly its role.

REFERENCES

1. Abdulbaki, A., El Masri, J., Ghazi, M., Kahl, K. G., Mocking, R. J. T., Salameh, P., Schuurman, R., Nuttin, B., & Krauss, J. K. (2025). Efficacy of deep brain stimulation for obsessive-compulsive disorder: umbrella review and updated meta-analysis. *Psychiatry Research*, *351*, 116651. https://doi.org/10.1016/J.PSYCHRES.2025.116651
2. Al-Husinat, L., Al-Bataineh, M., Hayajneh, R., Haneyah, D. O., Alrawabdeh, Q., Bani Melhem, R., Al Sharei, A., Ismail, M. I., Azzam, S., Al Sharie, S., & Varrassi, G. (2025). Deep brain stimulation for chronic pain: mechanisms, clinical applications, limitations, and future directions. *Frontiers in Medicine*, *12*, 1683991. https://doi.org/10.3389/FMED.2025.1683991
3. Asadi-Pooya, A. A., Brigo, F., Lattanzi, S., & Blumcke, I. (2023). Adult epilepsy. *Lancet (London, England)*, *402*(10399), 412–424. https://doi.org/10.1016/S0140-6736(23)01048-6
4. Bach, P., Luderer, M., Müller, U. J., Jakobs, M., Baldermann, J. C., Voges, J., Kiening, K., Lux, A., Visser-Vandewalle, V., Klosterkötter, J., Huys, D., Sommer, W., Weber, T., Bogerts, B., Kuhn, J., & Mann, K. (2023). Deep brain stimulation of the nucleus accumbens in treatment-resistant alcohol use disorder: a double-blind randomized controlled multi-center trial. *Translational Psychiatry 2023 13:1*, *13*(1), 49-. https://doi.org/10.1038/s41398-023-02337-1
5. Bahadori, A. R., Javadnia, P., Davari, A., Sheikhvatan, M., Ranji, S., Shafiee, S., & Tafakhori, A. (2024). Efficacy and safety of deep brain stimulation in drug resistance epilepsy: A systematic review and meta-analysis. *Neurosurgical Review*, *47*(1), 855. https://doi.org/10.1007/S10143-024-03090-9
6. Bishay, A. E., Lyons, A. T., Habib, D. R. S., Hughes, N. C., Long, I., Zargari, M., Qian, H., Paulo, D., Summers, J. E., Li, R., Bishay, S., Terry, D. P., Dawant, B. M., Ball, T. J., Konrad, P. E., Englot, D. J., Dhima, K., & Bick, S. K. (2025). Effect of deep brain stimulation on nonmotor symptoms in essential tremor. *Journal of Neurosurgery*, *143*(1), 38–52. https://doi.org/10.3171/2024.11.JNS241990
7. Boogers, A., Peeters, J., Van Bogaert, T., Rusz, J., Bogaert-Miclaus, C., Loret, G., De Vloo, P., Vandenberghe, W., Nuttin, B., & Mc Laughlin, M. (2023). Acute stimulation with symmetric biphasic pulses induces less ataxia compared to cathodic pulses in DBS for essential tremor. *Parkinsonism & Related Disorders*, *111*, 105435. https://doi.org/10.1016/J.PARKRELDIS.2023.105435
8. Bosch, T. J., Groth, C., Espinoza, A. I., Bharmauria, V., Flouty, O., & Singh, A. (2025). Cerebellar Oscillatory Patterns in Essential Tremor: Modulatory Effects of VIM-DBS. *Cerebellum*, *24*(2), 40-. https://doi.org/10.1007/S12311-025-01787-1/FIGURES/2
9. Cavallieri, F., Mulroy, E., & Moro, E. (2024). The history of deep brain stimulation. In *Parkinsonism and Related Disorders* (Vol. 121). Elsevier Ltd. https://doi.org/10.1016/j.parkreldis.2023.105980
10. Cui, B., Mocchi, M. M., Metzger, B. A., Kalva, P., Magnotti, J. F., Fiedorowicz, J. G., Waters, A., Kovach, C. K., Reed, Y. Y., Mathura, R. K., Steger, C., Pascuzzi, B., Kanja, K., Veerakumar, A., Tiruvadi, V., Crowell, A., Denison, L., Rozell, C. J., Pouratian, N., … Bijanki, K. R. (2025). Affective bias predicts changes in depression during deep brain stimulation therapy. *Frontiers in Human Neuroscience*, *19*, 1539857. https://doi.org/10.3389/FNHUM.2025.1539857/FULL
11. Fontaine, D., Leplus, A., Donnet, A., Darmon, N., Balossier, A., Giordana, B., Simonet, B., Isan, P., Regis, J., & Lanteri-Minet, M. (2025). Safety and feasibility of deep brain stimulation of the anterior cingulate and thalamus in chronic refractory neuropathic pain: a pilot and randomized study. *The Journal of Headache and Pain*, *26*(1), 35. https://doi.org/10.1186/S10194-025-01967-8

12. Ge, S., Wang, X., Li, N., Cai, Y., Wang, X., Su, M., Zheng, Z., Li, J., Wang, X., Qiu, C., Wang, J., Qu, Y., Gao, G., Chen, L., Li, Y., Liu, T., & Li, W. (2025). Effects of deep brain stimulation of the nucleus accumbens and anterior limb of the internal capsule on heroin addiction: Over five years of long-term follow-up in a prospective open-label pilot study. *Translational Psychiatry*, *15*(1), 415. https://doi.org/10.1038/S41398-025-03635-6
13. Giacobbe, P., Rizvi, S. J., Ceniti, A. K., Tomlinson, G., Elias, G. J. B., Germann, J., Styra, R., Lozano, A. M., & Kennedy, S. H. (2025). Deep Brain Stimulation to the Subgenual Cingulate Gyrus for Treatment-Resistant Depression: A Randomized Controlled Trial and 2-Year Long-Term Follow-Up: Stimulation cérébrale profonde du gyrus cingulaire subgénual pour traiter la dépression résistante au traitement : Essai contrôlé à répartition aléatoire et suivi à long terme sur deux ans. *Canadian Journal of Psychiatry. Revue Canadienne de Psychiatrie*, 7067437251369226. https://doi.org/10.1177/07067437251369226
14. Hu, T., Xie, H., Shan, M., Sang, L., Yang, B., Zhang, Q., Gao, D., Jiao, Y., Guo, Q., Li, S., Wang, Y., Du, X., Yang, A., Meng, F., Zhang, J., Zhang, K., & Zhang, H. (2025). Long-term efficacy of anterior nucleus of the thalamus deep brain stimulation in drug-resistant epilepsy: a 5-year multicenter study. *BMC Medicine*, *23*(1), 615. https://doi.org/10.1186/S12916-025-04465-5
15. Jakobs, M., Fomenko, A., Lozano, A. M., & Kiening, K. L. (2019). Cellular, molecular, and clinical mechanisms of action of deep brain stimulation—a systematic review on established indications and outlook on future developments. *EMBO Molecular Medicine*, *11*(4). https://doi.org/10.15252/EMMM.201809575/ASSET/6CD26C70-0244-4704-A38A-F0F83ECEC1D2/ASSETS/GRAPHIC/EMMM201809575-FIG-0007-M.PNG
16. Kim, S., Jung, S., Lee, S., Joo, E. Y., Seo, D.-W., & Shon, Y.-M. (2025). Cognitive outcomes after deep brain stimulation in drug-resistant epilepsy: A comparison of anterior thalamic and hippocampal stimulation. *Epilepsia Open*, *10*(5), 1462–1474. https://doi.org/10.1002/epi4.70107
17. Kondapavulur, S., Silva, A. B., & Wang, D. D. (2022). Ventral Intermediate Nucleus of the Thalamus versus Posterior Subthalamic Area: Network Meta-Analysis of DBS Target Site Efficacy for Essential Tremor. *Stereotactic and Functional Neurosurgery*, *100*(4), 224–235. https://doi.org/10.1159/000522573
18. Majdi, A., Deng, Z., Sadigh-Eteghad, S., De Vloo, P., Nuttin, B., & Mc Laughlin, M. (2023). Deep brain stimulation for the treatment of Alzheimer's disease: A systematic review and meta-analysis. *Frontiers in Neuroscience*, *17*, 1154180. https://doi.org/10.3389/FNINS.2023.1154180/BIBTEX
19. Riberas-Sánchez, A., Puig-Parnau, I., Vila-Solés, L., García-Brito, S., Aldavert-Vera, L., Segura-Torres, P., Huguet, G., & Kádár, E. (2024). Intracranial self-stimulation reverses impaired spatial learning and regulates serum microRNA levels in a streptozotocin-induced rat model of Alzheimer disease. *Journal of Psychiatry & Neuroscience*, *49*(2), E96–E108. https://doi.org/10.1503/JPN.230066
20. Sankar, T., Chakravarty, M. M., Bescos, A., Lara, M., Obuchi, T., Laxton, A. W., McAndrews, M. P., Tang-Wai, D. F., Workman, C. I., Smith, G. S., & Lozano, A. M. (2015). Deep Brain Stimulation Influences Brain Structure in Alzheimer's Disease. *Brain Stimulation*, *8*(3), 645–654. https://doi.org/10.1016/J.BRS.2014.11.020
21. Sedrak, M. F., Chang, R. N., Pezeshkian, P., Reyes, C. E., Prentice, H. A., Paxton, E. W., Skordilis, M. A., Hickey, P. T., Srivastava, S., & Anderson, R. (2025). Deep brain stimulation within a multi-center US-based healthcare system – A descriptive epidemiologic review from 2010 through 2021. *Journal of Clinical Neuroscience*, *139*. https://doi.org/10.1016/j.jocn.2025.111428
22. Shaheen, N., Shaheen, A., Elgendy, A., Bezchlibnyk, Y. B., Zesiewicz, T., Dalm, B., Jain, J., Green, A. L., Aziz, T. Z., & Flouty, O. (2023). Deep brain stimulation for chronic pain: a systematic review and meta-analysis. *Frontiers in Human Neuroscience*, *17*, 1297894. https://doi.org/10.3389/FNHUM.2023.1297894
23. Shea, J. M., Feigen, C. M., Eskandar, E. N., & Killian, N. J. (2025). Mechanisms of DBS: from informational lesions to circuit modulation and implications in OCD. *Frontiers in Human Neuroscience*, *19*, 1492744. https://doi.org/10.3389/FNHUM.2025.1492744
24. Shih, L. C. (2025). Essential Tremor. *CONTINUUM: Lifelong Learning in Neurology*, *31*(4), 979–999. https://doi.org/10.1212/CONT.0000000000001605
25. Trevisiol, A., Beckett, T., Vila, M. B., Hill, M., McLaurin, J., & Stefanovic, B. (2025). Deep brain stimulation-induced normalization of hippocampal synchrony in a transgenic rat model of Alzheimer's disease. *Theranostics*, *15*(18), 10064–10075. https://doi.org/10.7150/THNO.110292
26. Xue, T., Qiu, Y., Tian, W., Xie, H., Fan, S., Fan, H., Xie, M., Ye, M., Wang, Z., Ning, T., Han, C., Zhang, H., Yang, A., Sang, L., Germann, J., Boutet, A., Tam, J., Lozano, A. M., Meng, F., … Zhang, J. (2025). Optimal Stimulation Sites and Connectomes for GPi and STN-DBS in Cervical Dystonia. *CNS Neuroscience and Therapeutics*, *31*(8), e70561. https://doi.org/10.1111/cns.70561
27. Zoghdan, H. E.-S. H., Salem, T. M. L., Abouelela Abdelmawla Radwan, H. M., & Youssef El-Mashad, M. G. (2024). Outcomes after Deep Brain Stimulation for Generalized Dystonia. *QJM: An International Journal of Medicine*, *117*(Supplement_2). https://doi.org/10.1093/QJMED/HCAE175.563