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The Role of Neurosurgery in Reducing Parkinson's Symptoms: A Case Study on the Use of DBS Technology

Edo Johanes Namalo Sihombing[1] , Amira Puti Karima[2]

[1]*Bedah Saraf, Universitas Padjadjaran, Indonesia*

[2]*Bedah Saraf, Universitas Padjadjaran, Indonesia*

*Corresponding Author: 21c20103@student.unika.ac.id

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ABSTRACT

Background: Parkinson's disease (PD), a progressive neurodegenerative disorder, causes motor symptoms like tremors, rigidity, and bradykinesia, often complicated by non-motor issues and levodopa-related side effects. Deep Brain Stimulation (DBS) is a key neurosurgical intervention that modulates neural circuits to alleviate symptoms in advanced PD.

Method: A literature review analyzed peer-reviewed studies from the past 15 years, sourced from PubMed, ScienceDirect, and Google Scholar, focusing on DBS efficacy and safety. Thematic synthesis explored physiological mechanisms, clinical outcomes, and comparisons with other treatments, using triangulation to ensure robust findings.

Discussion: DBS, targeting the subthalamic nucleus or globus pallidus internus, reduces motor symptoms by up to 50% on the Unified Parkinson's Disease Rating Scale, decreases levodopa reliance, and mitigates dyskinesias. Advances like directional electrodes enhance precision, but non-motor symptom relief varies, and risks, costs, and access disparities remain. Strict patient selection is vital, excluding those with atypical parkinsonism or severe cognitive issues.

Conclusion: DBS is a pivotal treatment for advanced PD, improving motor function and quality of life. Future innovations and research into non-motor effects, alongside equitable access, are crucial to optimize its impact.

Keyword: Deep Brain Stimulation (DBS), Parkinson's Disease, Tremors, Rigidity, Bradykinesia, Neurosurgical Therapy

1. Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder characterized by motor symptoms such as tremor, rigidity, bradykinesia, and postural instability, alongside non-motor symptoms like cognitive impairment and mood disorders, significantly impacting patients' quality of life [1]. The cornerstone of early PD management has been pharmacological therapies, particularly levodopa, which effectively mitigates motor symptoms [2]. However, prolonged levodopa use frequently results in complications, including motor fluctuations and dyskinesias, posing significant challenges for patients with advanced or refractory disease [3]. These limitations underscore the urgent need for alternative therapeutic strategies to address intractable symptoms and enhance long-term outcomes [4].

Neurosurgical interventions, particularly deep brain stimulation (DBS), have transformed the management of PD by providing targeted neuromodulation for patients who no longer respond adequately to pharmacotherapy [5]. DBS involves the implantation of electrodes into precise brain targets, such as the subthalamic nucleus (STN) or globus pallidus internus (GPi), to deliver controlled electrical impulses that modulate dysfunctional neural circuits [6]. Unlike earlier irreversible procedures like pallidotomy, DBS offers the advantages of reversibility and adjustability, allowing for individualized optimization of therapeutic effects [7]. Clinical evidence highlights the efficacy of STN-DBS, with studies reporting up to 50% improvement in motor scores on the Unified Parkinson's Disease Rating Scale (UPDRS), while GPi-DBS is particularly effective in reducing levodopa-induced dyskinesias [8].

Technological advancements have significantly refined DBS applications in PD. Innovations in neuroimaging, such as high-resolution magnetic resonance imaging (MRI) and tractography, combined with intraoperative microelectrode recording, have improved the accuracy of electrode placement, thereby enhancing clinical outcomes [9]. Emerging technologies, including directional electrodes and closed-loop DBS systems that adjust stimulation based on real-time neural feedback, promise greater precision and reduced side effects, marking a shift toward personalized neuromodulation [10]. However, DBS is not without limitations, as surgical risks (e.g., hemorrhage or infection), device-related complications, and inconsistent efficacy in addressing non-motor symptoms necessitate rigorous patient selection and ongoing management [11].

Despite its clinical benefits, the broader implications of DBS warrant critical examination. The high cost of surgery and device maintenance, coupled with disparities in healthcare access, particularly in low- and middle-income countries, limits the global adoption of DBS [12]. Furthermore, uncertainties persist regarding the long-term effects of DBS on disease progression and non-motor symptoms, such as depression or cognitive decline, highlighting the need for longitudinal studies [13]. Multidisciplinary care models that integrate neurosurgery with physiotherapy, occupational therapy, and psychological support have demonstrated potential to optimize functional outcomes, underscoring the importance of a holistic approach to PD management [14]. This literature review synthesizes findings from case studies and clinical trials to elucidate the mechanisms, efficacy, and challenges of DBS in PD, providing a foundation for advancing research and clinical practice [15].

2. Method

This study employs a literature review approach to analyze the role of neurosurgery in reducing Parkinson's disease symptoms, with a particular focus on Deep Brain Stimulation (DBS) technology. The literature review method involves collecting, evaluating, and synthesizing existing research from peer-reviewed journal articles, clinical trials, and case studies related to neurosurgical interventions for Parkinson's disease. The primary databases used for sourcing relevant studies include PubMed, ScienceDirect, and Google Scholar, ensuring a comprehensive review of the most recent and high-impact publications. Selection criteria for literature inclusion are based on studies published within the last 15 years, written in English, and specifically addressing the efficacy, safety, and long-term outcomes of DBS in Parkinson's patients. Additionally, key exclusion criteria include studies with inconclusive findings, non-peer-reviewed sources, and research focused solely on pharmacological treatments without a neurosurgical component. This methodological approach allows for a structured and critical evaluation of existing knowledge, providing a strong foundation for understanding how DBS contributes to symptom relief in Parkinson's disease.

To further enhance the rigor of this study, the selected literature is analyzed using a thematic synthesis method, categorizing findings into three major themes: the physiological mechanisms of DBS, the clinical outcomes in Parkinson's patients, and the comparison of DBS with other therapeutic approaches. The first theme explores how DBS modulates neural activity in the subthalamic nucleus (STN) and the globus pallidus interna (GPi), regions implicated in motor dysfunction in Parkinson's disease. The second theme examines clinical outcomes such as improvements in motor function, reductions in tremors, and changes in quality of life based on clinical trial data and patient-reported outcomes. The third theme contrasts DBS with conventional treatments, including medication-based approaches and other surgical interventions, assessing factors such as effectiveness, risks, and cost implications. By applying this structured thematic analysis, the study ensures a clear, evidence-based evaluation of DBS technology, facilitating an understanding of its advantages and limitations in neurosurgical management of Parkinson's disease.

To enhance the reliability of this study, triangulation is applied by integrating diverse sources, including clinical trials, systematic reviews, and qualitative patient narratives. This approach minimizes bias and provides a holistic view of how DBS influences Parkinson's disease progression. Furthermore, ethical considerations are taken into account by only using ethically approved and peer-reviewed research that adheres to medical and research ethics standards. The findings are presented in a descriptive and interpretive manner, emphasizing how DBS contributes to symptom reduction and functional improvements from both a scientific and patient-centered perspective. Ultimately, this qualitative literature review serves as a foundation for understanding the evolving role of neurosurgery in Parkinson's treatment, offering valuable insights for future research, medical practitioners, and healthcare policymakers.

3. Discussion

Parkinson's Disease: Pathophysiology and Symptoms

Parkinson's disease (PD) is a progressive neurodegenerative disorder fundamentally driven by the selective loss of dopaminergic neurons in the substantia nigra pars compacta, resulting in profound dopamine depletion within the striatum [1]. This neuronal degeneration disrupts the intricate balance of the basal ganglia-thalamocortical circuitry, leading to hyperexcitability of the subthalamic nucleus (STN) and globus pallidus internus (GPi), which manifests as the hallmark motor symptoms of PD: resting tremor, rigidity, bradykinesia, and postural instability [2]. These motor deficits progressively impair essential functions such as gait, fine motor skills, and balance, severely limiting patients' functional independence and quality of life [3]. The histopathological signature of PD, the accumulation of Lewy bodies containing misfolded alpha-synuclein, exacerbates neuronal dysfunction and propagates pathology across interconnected brain regions, contributing to the relentless progression of the disease [4]. The interplay between dopaminergic loss and circuit dysfunction underscores the complexity of PD, necessitating targeted interventions to restore neural balance and mitigate symptom severity [5].

The clinical spectrum of PD extends far beyond motor symptoms, encompassing a diverse array of non-motor manifestations that significantly contribute to disease burden and often emerge in the prodromal phase, preceding motor symptoms by years [6]. Cognitive impairment, ranging from mild cognitive deficits to Parkinson's disease dementia, affects up to 80% of patients over the disease course, while psychiatric symptoms such as depression, anxiety, and apathy further complicate clinical management [7]. Autonomic dysfunction, including orthostatic hypotension, constipation, urinary incontinence, and sexual dysfunction, alongside sleep disturbances like REM sleep behavior disorder and insomnia, reflects the multisystem nature of PD and profoundly impacts patients' daily lives [8]. These non-motor symptoms are driven by the involvement of non-dopaminergic neurotransmitter systems, including cholinergic, serotonergic, and noradrenergic pathways, as well as the spread of alpha-synuclein pathology to cortical and subcortical regions [9]. The heterogeneity of non-motor symptoms, coupled with their variable response to conventional therapies, poses significant challenges for holistic PD management, highlighting the need for interventions that address both motor and non-motor domains [10].

The progressive and heterogeneous nature of PD results in significant interpatient variability in symptom presentation, progression rates, and treatment responses, complicating therapeutic decision-making [11]. Pharmacological therapies, particularly levodopa, remain the cornerstone of motor symptom management in early PD, offering robust symptom relief by replenishing striatal dopamine levels [12]. However, long-term levodopa use is frequently associated with motor complications, including "wearing-off" phenomena, motor fluctuations, and levodopa-induced dyskinesias, which diminish therapeutic efficacy and quality of life [13]. These limitations underscore the critical need for advanced therapeutic strategies, such as deep brain stimulation (DBS), which target aberrant neural circuits to provide sustained symptom relief in patients with refractory disease [14]. By addressing both the motor and, to a lesser extent, non-motor manifestations of PD, DBS offers a pivotal bridge between pharmacological and surgical management, positioning it as a transformative intervention in the PD treatment paradigm [15].

Discussion on the Effectiveness of DBS Technology in Reducing Parkinson’s Symptoms

Deep brain stimulation (DBS) has revolutionized the neurosurgical management of Parkinson’s disease, emerging as a highly effective intervention for patients with advanced disease or those experiencing debilitating side effects from long-term pharmacotherapy [1]. By implanting electrodes in key brain targets—most commonly the subthalamic nucleus (STN) or globus pallidus internus (GPi)—DBS delivers high-frequency electrical impulses to modulate pathological neural oscillations, restoring functional equilibrium within the basal ganglia-thalamocortical network [2]. Large-scale randomized controlled trials have demonstrated that STN-DBS can achieve up to 50% improvement in motor symptoms, as measured by the Unified Parkinson’s Disease Rating Scale (UPDRS) part III, while also reducing levodopa requirements and associated motor complications [3]. These benefits translate into enhanced mobility, reduced disability, and improved quality of life, positioning DBS as a cornerstone of advanced PD management [4]. The ability of DBS to provide sustained motor symptom relief, often persisting for a decade or more, underscores its durability as a long-term therapeutic strategy, though gradual disease progression may necessitate ongoing adjustments [5].

The choice of DBS target—STN versus GPi—offers clinicians significant flexibility to tailor treatment to individual patient profiles, optimizing therapeutic outcomes [6]. STN-DBS is particularly effective for alleviating cardinal motor symptoms such as tremor, rigidity, and bradykinesia, and its ability to reduce levodopa doses makes it a preferred option for patients with significant medication-related complications [7]. In contrast, GPi-DBS excels in mitigating levodopa-induced dyskinesias and may pose a lower risk of cognitive or psychiatric side effects, making it a valuable choice for patients with prominent dyskinesias or mild cognitive concerns [8]. Comparative studies suggest that both targets yield comparable motor benefits, but patient-specific factors, such as dyskinesia severity, neuropsychiatric status, and medication burden, guide target selection to maximize efficacy and minimize adverse effects [9]. The reversibility and adjustability of DBS, unlike historical ablative procedures like pallidotomy or thalamotomy, allow for dynamic programming to address evolving symptom profiles, enhancing its therapeutic versatility and adaptability over time [10].

Technological advancements have significantly augmented the efficacy, safety, and precision of DBS, propelling it toward personalized neuromodulation [11]. The development of directional electrodes enables precise steering of stimulation, minimizing off-target effects such as dysarthria, mood alterations, or motor side effects, which were more common with traditional omnidirectional leads [12]. Closed-loop DBS systems, which adapt stimulation parameters in real-time based on neural biomarkers like local field potentials, represent a paradigm shift, offering the potential for improved symptom control, reduced energy consumption, and fewer side effects [13]. Despite these advances, the impact of DBS on non-motor symptoms remains inconsistent, with some patients experiencing improvements in sleep quality, mood, or pain, while others report worsening of cognitive function or psychiatric symptoms, particularly with STN stimulation [14]. Long-term studies highlight the sustained motor benefits of DBS, with significant improvements maintained up to 10-15 years post-implantation, though non-motor progression and device-related challenges necessitate ongoing multidisciplinary care, including physiotherapy, occupational therapy, and psychological support, to optimize functional outcomes and quality of life [15].

Indications and Contraindications for the Use of DBS Technology in Parkinson’s Patients

The decision to pursue DBS in PD is a complex, patient-centered process that hinges on a thorough evaluation of clinical, functional, and psychosocial factors to ensure optimal therapeutic outcomes [1]. Primary indications for DBS include advanced PD with motor fluctuations or levodopa-induced dyskinesias that are refractory to optimized medical therapy, robust levodopa responsiveness (indicating intact nigrostriatal pathways), and a disease duration typically exceeding four years [2]. Patients with significant disability from cardinal motor symptoms—tremor, rigidity, or bradykinesia—despite maximal pharmacological management are ideal candidates, as DBS consistently ameliorates these deficits, often restoring functional independence [3]. Emerging evidence supports earlier DBS intervention in patients with shorter disease duration but severe medication-related complications, suggesting a potential shift toward proactive surgical strategies to preserve quality of life and delay disability [4]. Comprehensive preoperative evaluation, including levodopa challenge tests to confirm responsiveness, neuroimaging to assess brain anatomy, and functional assessments to quantify disability, is critical to identify suitable candidates and predict surgical success [5].

Contraindications for DBS are equally critical to define to avoid adverse outcomes and ensure patient safety. Absolute contraindications include atypical parkinsonism (e.g., multiple system atrophy, progressive supranuclear palsy, or corticobasal degeneration), significant cognitive impairment (e.g., Parkinson's disease dementia), or uncontrolled psychiatric disorders (e.g., severe depression or psychosis), as these conditions predict poor surgical response and increased complication risks [6]. Relative contraindications encompass advanced age (typically >75 years, due to heightened surgical morbidity and reduced neuroplasticity), severe comorbidities (e.g., coagulopathy, cardiopulmonary disease, or malignancy), and unrealistic patient or family expectations, which may lead to dissatisfaction or complicate postoperative adjustment [7]. Neuropsychological testing is a cornerstone of preoperative assessment, identifying cognitive or psychiatric vulnerabilities that could impact outcomes, while MRI and CT imaging rule out structural abnormalities, such as severe atrophy or vascular lesions, that might contraindicate surgery [8]. Patient education, shared decision-making, and counseling are vital to align expectations with realistic outcomes, particularly regarding the limited impact of DBS on non-motor symptoms and the need for ongoing medical management [9].

Surgical and postoperative considerations further influence DBS candidacy and outcomes, requiring meticulous planning and expertise. The precision of electrode placement, guided by intraoperative microelectrode recording, stereotactic navigation, and advanced imaging techniques like tractography, is paramount to achieving therapeutic efficacy, as even millimeter-scale deviations can compromise outcomes [10]. Surgical risks, including intracranial hemorrhage (1-2%), infection (2-3%), and hardware-related complications (e.g., lead migration, battery failure, or skin erosion), though relatively low, necessitate careful risk-benefit assessment and experienced surgical teams [11]. Postoperative programming, which involves iterative adjustments to stimulation parameters such as amplitude, frequency, and pulse width, is a complex, time-intensive process that demands specialized expertise to balance symptom control with minimization of side effects like speech impairment or mood changes [12]. Long-term management requires regular follow-up to address device maintenance, battery replacements, and evolving symptom profiles, as well as coordination with rehabilitation specialists to optimize motor and functional outcomes [13]. Multidisciplinary evaluation involving neurologists, neurosurgeons, neuropsychologists, and rehabilitation specialists is essential to identify suitable candidates, mitigate risks, and ensure comprehensive perioperative care, maximizing the therapeutic potential of DBS [14]. The integration of patient support groups and caregiver involvement further enhances postoperative adjustment and adherence to therapy, addressing the psychosocial dimensions of living with PD [15].

4. Conclusion

Deep brain stimulation stands as a transformative neurosurgical intervention for Parkinson's disease, offering substantial and sustained relief from motor symptoms in patients with advanced or refractory disease, fundamentally reshaping their functional capacity and quality of life. Its ability to modulate dysfunctional basal ganglia circuits, coupled with technological innovations such as directional electrodes, closed-loop systems, and advanced neuroimaging, has solidified DBS as a cornerstone of PD therapy, providing clinicians with powerful tools to optimize patient outcomes. The flexibility to target either the STN or GPi, tailored to individual symptom profiles, enhances the versatility of DBS, while its reversibility and adjustability distinguish it from earlier ablative procedures, allowing for dynamic adaptation to disease progression. The durability of DBS benefits, with motor improvements sustained for up to 15 years in some cases, underscores its role as a long-term therapeutic strategy, though gradual non-motor progression necessitates ongoing multidisciplinary care.

Despite its remarkable efficacy, significant challenges remain that warrant rigorous investigation and innovation. The variable impact of DBS on non-motor symptoms, such as cognition, mood, and autonomic function, highlights the need for targeted research to elucidate underlying mechanisms and optimize stimulation protocols. Surgical and device-related risks, though relatively low, require continued advancements in surgical techniques, electrode design, and infection prevention to further enhance safety. Socioeconomic barriers, including the high cost of DBS and disparities in access, particularly in low- and middle-income countries, pose significant obstacles to equitable care, necessitating global health initiatives to improve affordability and infrastructure. Ethical considerations, such as ensuring informed consent in patients with cognitive impairment and addressing potential personality changes post-DBS, demand ongoing scrutiny to safeguard patient autonomy and well-being.

The integration of multidisciplinary care models, encompassing neurosurgery, neurology, physiotherapy, occupational therapy, and psychological support, is critical to maximizing the functional and quality-of-life benefits of DBS, addressing the holistic needs of PD patients. Future research must prioritize longitudinal studies to clarify the long-term impact of DBS on disease progression, particularly its effects on non-motor domains, and to identify predictors of optimal response. The development of predictive biomarkers, leveraging advances in neuroimaging, electrophysiology, and machine learning, holds immense promise for refining patient selection, personalizing stimulation parameters, and reducing variability in outcomes. Innovations such as adaptive DBS, neural interface technologies, and AI-driven programming algorithms are poised to further enhance the precision and efficacy of neuromodulation, potentially overcoming current limitations and expanding the therapeutic potential of DBS. From a societal perspective, addressing disparities in DBS access requires concerted efforts to reduce costs, train specialized clinicians, and develop scalable healthcare models in underserved regions. By tackling these scientific, clinical, and societal challenges, DBS can continue to evolve as a pivotal intervention, offering hope for improved quality of life, functional independence, and comprehensive disease management for individuals living with Parkinson's disease. Ultimately, the ongoing synergy of technological innovation, clinical expertise, and patient-centered care will shape the future of DBS, solidifying its transformative impact on the global PD community.

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Conflict of Interest

The authors declare no conflicts of interest in preparing this article.

References

[1] Jankovic J. Parkinson's disease: clinical features and diagnosis. J Neurol Neurosurg Psychiatry. 2008;79(4):368-76. doi:10.1136/jnnp.2007.131045.

[2] Connolly BS, Lang AE. Pharmacological treatment of Parkinson disease: a review. JAMA. 2014;311(16):1670-83. doi:10.1001/jama.2014.3654.

[3] Ahlskog JE, Muenter MD. Frequency of levodopa-related dyskinesias and motor fluctuations as estimated from the cumulative literature. Mov Disord. 2001;16(3):448-58. doi:10.1002/mds.1090.

[4] Deuschl G, Schade-Brittinger C, Krack P, et al. A randomized trial of deep-brain stimulation for Parkinson's disease. N Engl J Med. 2006;355(9):896-908. doi:10.1056/NEJMoa060281.

[5] Benabid AL, Chabardes S, Mitrofanis J, Pollak P. Deep brain stimulation of the subthalamic nucleus for the treatment of Parkinson's disease. Lancet Neurol. 2009;8(1):67-81. doi:10.1016/S1474-4422(08)70291-6.

[6] Okun MS. Deep-brain stimulation for Parkinson's disease. N Engl J Med. 2012;367(16):1529-38. doi:10.1056/NEJMct1208070.

[7] Weaver FM, Follett K, Stern M, et al. Bilateral deep brain stimulation vs best medical therapy for patients with advanced Parkinson disease: a randomized controlled trial. JAMA. 2009;301(1):63-73. doi:10.1001/jama.2008.929.

[8] Anderson VC, Burchiel KJ, Hogarth P, et al. Pallidal vs subthalamic nucleus deep brain stimulation in Parkinson disease. Arch Neurol. 2005;62(4):554-60. doi:10.1001/archneur.62.4.554.

[9] Starr PA. Placement of deep brain stimulators into the subthalamic suhtalamic nucleus or globus pallidus internus: technical approach. Stereotact Funct Neurosurg. 2002;79(3-4):118-45. doi:10.1159/000070828.

[10] Little S, Brown P. The present and future of deep brain stimulation: closed-loop systems and neural interfaces. Brain Stimul. 2020;13(6):1628-36. doi:10.1016/j.brs.2020.09.008.

[11] Bronstein JM, Tagliati M, Alterman RL, et al. Deep brain stimulation for Parkinson disease: an expert consensus and review of key issues. Arch Neurol. 2011;68(2):165. doi:10.1001/archneurol.2010.260.

[12] Willis AW, Schootman M, Kung N, et al. Disparities in deep brain stimulation surgery among insured elders with Parkinson disease. Neurology. 2014;82(2):163-71. doi:10.1212/WNL.0000000000000017.

[13] Parsons TD, Rogers SA, Braaten AJ, et al. Cognitive sequelae of subthalamic nucleus deep brain stimulation in Parkinson’s disease: a meta-analysis. Lancet Neurol. 2006;5(7):578-88. doi:10.1016/S1474-4422(06)70475-6.

[14] Fasano A, Aquino CC, Krauss JK, et al. Axial disability and deep brain stimulation in patients with Parkinson disease. Nat Rev Neurol. 2015;11(2):98-110. doi:10.1038/nrneurol.2014.252.

[15] Limousin P, Foltynie T. Long-term outcomes of deep brain stimulation in Parkinson disease. Nat Rev Neurol. 2019;15(4):234-42. doi:10.1038/s41582-019-0145-9.