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# PHARMACOECONOMIC IMPACT OF POST–DEEP BRAIN STIMULATION MEDICATION USE AND ADVERSE EVENT PROFILE IN PATIENTS WITH PARKINSON'S DISEASE IN PAKISTAN

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## Abstract

***Background:*** *Deep Brain Stimulation (DBS) has been used successfully for the treatment of advanced Parkinson's disease (PD) and is known to be effective in managing the motor symptoms of PD, as well as reducing reliance on anti-Parkinsonian medications. But its pharmacoeconomic effects are still poorly known in LAMIC countries. The purpose of this study was to assess medication utilization, direct medication cost reduction and adverse event profile in PD patients in Pakistan after DBS.*

***Methodology:*** *A mixed retrospective–prospective observational pre–post study was performed in 50 Parkinson's disease (PD) patients who had undergone bilateral subthalamic nucleus (STN) DBS in a tertiary care center in Pakistan. Both pre-operative and post-operative data were retrieved from medical records and follow-up and telephonic interviews were used to gather the post-operative data. Medication use, direct medication expenses, and adverse events within six months of surgery were evaluated. Paired-sample tests were used to analyze data and a p value of $< 0.05$ was considered statistically significant.*

***Results:*** *88.0% (44/50) of patients had reduction in medication and 84.0% (42/50) of patients had reduction in direct medication costs. The expenditure of medicines after the surgery was significantly less than before the surgery ($p<0.0001$). Thirty-four percent (17/50) of patients reported adverse events, most of which were mild to moderate and short-lived. With the Naranjo Adverse Drug Reaction Probability Scale, 16.0% (8/50) of patients suffered from adverse drug reactions.*

***Finding:*** *DBS was shown to be significantly associated with decreased medication use and direct medication expenditures and cost without any adverse impact on patient safety. The results are important and demonstrate the pharmacoeconomic benefit of DBS in lowering the chronic drug burden for PD patients in resource-constrained health care systems. Additional multi-center trials with QOL data and comprehensive economic evaluations are recommended.*

## INTRODUCTION

Parkinson's disease (PD) is a chronic, progressive neurodegenerative disorder, which presents with the cardinal motor symptoms of tremor, rigidity, bradykinesia, and postural instability, associated with a loss of dopaminergic neurons in the substantia nigra (Dorsey et al., 2018). It is known to be one of the most prevalent movement disorders in the world, and the prevalence of the disorder has become

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significantly higher as a result of population ageing and increased life expectancy (Dorsey et al., 2018). As PD becomes a growing burden, there are substantial implications for the health services, especially in low and middle income countries (LMICs), where access to specialised neurological services and advanced treatment options is limited (Kalhoro & Hashim, 2023). The epidemiological and economic burden of PD is now being recognized more and more in Pakistan and more and more patients are now requiring long-term medical/surgical treatment (Khan et al., 2024; Idrees et al., 2024). Traditionally, the most important management strategy for PD has been pharmacotherapy, such as levodopa, dopamine agonists, monoamine oxidase-B inhibitors, catechol-O-methyltransferase inhibitors, anticholinergics and other adjunctive medications (Nakanishi & Takahashi, 2022). While these drugs are very effective in reducing symptoms at the early stages of the disease, motor fluctuations, dyskinesias, wearing-off phenomena, and adverse drug reactions often compromise their long-term effectiveness (Deuschl et al., 2006; Nakanishi & Takahashi, 2022). Polypharmacy, non-adherence/compliance and increased health care costs are common as the disease advances and patients need more drugs and higher doses (Diamond & Jankovic, 2005). As a result, health care systems and patients have a significant economic cost burden due to the need for lifelong pharmacological therapy (Tomaszewski & Holloway, 2001).

One of the most successful surgical procedures for late-stage PD is Deep Brain Stimulation (DBS). DBS was originally developed by Benabid et al. (1987) for implantation of electrodes in the brain regions, typically globus pallidus internus (GPi) and subthalamic nucleus (STN), to deliver controlled electrical stimulation to enhance motor function. In the last 30 years, DBS has emerged as a viable treatment for patients with medication-resistant symptoms or "uncontrollable" motor-related side effects of PD (Bronstein et al., 2011; Deuschl et al., 2013). DBS has been consistently shown to have significantly better motor outcomes than medical therapy alone (Deuschl et al., 2006; Schuepbach et al., 2013; Lachenmayer et al., 2021), better disability reduction and improved quality of life in patients with DPDR.

Apart from its clinical advantage, DBS has garnered significant attention due to its possible pharmacoeconomic benefits. Previous studies have shown significant decreases in levodopa-equivalent daily dose (LEDD) and medication burden as well as direct medication cost after DBS (Tomaszewski & Holloway, 2001; Weaver et al., 2012; Ng et al., 2020). Further long-term follow-up studies have demonstrated that STN-DBS is also associated with marked reductions in medication usage and sustained motor improvements (Odekerken et al., 2013; Yuan et al., 2023). Moreover, there are indications that minimising dependency on medication can lead to fewer adverse events associated with prescription medications and better adherence (Ng et al., 2020; Khan et al., 2024).

While effective, DBS also has some complications. Various studies have documented adverse events associated with surgery, stimulation, and medications, highlighting the need for ongoing safety surveillance (Burdick et al., 2010; Buhmann et al., 2017). Any adverse events can vary from transient neurological events to complications that necessitate medical intervention related to the device (Buhmann et al., 2017). Therefore, the standardized recording and evaluation of adverse events are critical to be able to identify the overall risk-benefit profile of DBS and use this to inform clinical decision-making (Burdick et al., 2010; Turnbull et al., 2023). The use of DBS in neurological rehabilitation and management of movement disorders has also been enhanced by the development of new technologies in the field of neuromodulation and neurostimulation and the emergence of new brain-computer interface applications (Ortega-Robles et al., 2025; Lovejoy, 2023; Lloret-Torres, 2023). There is also growing evidence that electrical brain stimulation techniques can be applied to a range of neurological and psychiatric conditions, suggesting the wide potential applications of neuromodulation-based therapies (Fenoy et al., 2022; Rodrigues et al., 2019). Advances in electrode placement techniques and stimulation programming have also improved the accuracy of treatment and outcomes in PD patients receiving DBS (Yuan et al., 2023; Agrawal et al., 2021).

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While there is extensive literature on the economic and clinical effectiveness of DBS in international context, there is limited evidence available in Pakistan. While the existing local studies have focused mainly on motor outcomes, drug reduction, and overall efficacy of treatment, relatively less emphasis has been put on pharmacoeconomic outcomes and adverse events profiles (Kalhoro & Hashim, 2023; Khan et al., 2024; Idrees et al., 2024). Furthermore, and importantly, the differences in the health sector infrastructure, access to health care services, price of medicines, and patient population require country-specific studies. Hence the present study was conducted to assess post DBS medication use, direct cost reduction in medication and profile of adverse events in PD patients in Pakistan. The results will offer insightful local information on the pharmaco-economic effects and safety of DBS, aiding healthcare professionals, policy makers and planners in their efforts to better manage Parkinson's disease.

## 1. Literature Review

Deep brain stimulation (DBS) is an established neuromodulation therapy for Parkinson disease (PD), essential tremor (ET), dystonia, and obsessive-compulsive disorder (OCD). Since its resurgence in the late 1980s, DBS has become an important non-pharmacological alternative that can substantially modify or reduce pharmacological management. Despite widespread clinical adoption, reported adverse event (AE) rates vary widely in the literature — ranging from 8.6% to over 50% — a disparity that Videnovic and Metman attributed primarily to the absence of standardized, prospective reporting methodology rather than true differences in surgical safety.

Addressed this gap by implementing a pharmaceutical-grade, prospective AE surveillance system at the University of Florida Movement Disorders Center, modeled on clinical trial pharmacovigilance standards as defined by ICH E2A guidelines. Over 270 DBS procedures in 198 patients (mean age 57.2 ± 15.8 years), 300 AEs were recorded in 54.1% of procedures — substantially higher than most published series. AEs were classified by severity (mild 34.1%, moderate 35.5%, severe 30.4%), causality to stimulation, and causality to surgery, mirroring the dual-axis attribution approach used in adverse drug reaction (ADR) assessment.

The most clinically significant finding was that despite the high AE rate, neither AE presence nor severity was associated with worse quality of life (QOL), motor function, or Patient Global Impression Scale (PGIS) scores at six months ($p = 0.22$ for QOL; $p = 0.59$ for UPDRS in PD patients). Importantly, 82.6% of AEs were transient, analogous to titration-phase adverse drug reactions that resolve with dose optimization. This dissociation between AE burden and functional outcome mirrors well-established patterns in pharmacotherapy, where agents such as chemotherapeutics carry high documented toxicity profiles yet deliver significant net clinical benefit.

From a clinical pharmacist's perspective, this study reinforces several key practice implications. The most prevalent AE category — mental status decline (17.7%) — directly warrants psychotropic pharmacotherapy co-management. Device-related infections requiring IV antibiotics (1.7%) and hardware removal (2.3%) necessitate evidence-based antibiotic stewardship. As DBS expands into neuropsychiatric indications such as OCD and treatment-resistant depression, pharmacist involvement in integrated safety monitoring will become increasingly essential. The standardized AE capture methodology proposed by provides a pragmatic framework for multi-center AE registries, enabling the kind of comparative safety data that currently supports rational pharmacotherapy decision-making.

## 2. Methodology

### Study Design

The study was an observational within subjects (pre–post) mixed retrospective–prospective pharmacoeconomic analysis (PEA) using each patient as his/her own control. This design was able to accommodate for inter-individual baseline disease severity, comorbidities, and initial pharmacological treatment. The lack of a medically managed control group, though, makes it difficult to interpret the results as evidence of an association between DBS and surgical outcomes, or as evidence for causality. Patients were not subjected to any clinical

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interventions by investigators, and were followed up by their treating neurosurgeons and neurologists.

**Study Setting and Duration**

The patients underwent Deep Brain Stimulation (DBS) surgery were screened for inclusion from November 2025 to end February 2026 and registered in the database of the medical technology coordinating organization in Pakistan for DBS systems. The study was carried out in Punjab Institute of Neurosciences (PINS), Lahore, Pakistan. Data collection was active from the first week of November 2025 to the last week of February 2026.

**Study Population**

The patients studied were all diagnosed with Parkinson's disease (PD) prior to surgery based on standard clinical criteria. The available national DBS cohort treated and followed-up in PINS Lahore was used to identify patients who fulfilled the eligibility criteria.

**Inclusion and Exclusion Criteria**

Patients had to be 18 years of age or older at implant and have a full clinical history and full medication information before and after surgery for at least six months, and be able to be contacted for structured follow up. Any patient who had undergone a DBS revision or reimplantation procedure and/or received device explantation during the study period, as well as those with significant confounding neurological and psychiatric conditions like significant dementia, uncontrolled psychosis or having a concurrent stroke, were excluded from this study.

**Sample Size and Sampling Technique**

DBS surgical cohort was available in Pakistan's healthcare system in a limited and specially selected manner, hence non-probability purposive sampling was employed. This strategy allowed for recruitment of available national DBS population, and it is possible this may have led to selection bias and reduced generalisability to the wider population with Parkinson's disease. The minimum sample size was determined to be 46 patients with 80% power, $\alpha$ equal to 0.05 (two-tailed) and ± SD 5,000 for between-within subjects paired comparisons. Due to attrition and incomplete data, a final sample of 50 randomly eligible consecutive patients was recruited.

**Data Collection Procedure**

Historical database records were used to collect pre-operative medication data before the implant and structured telephonic interviews and clinical follow-up records were used to collect post-operative data. To standardize economic evaluation, the six-month assessment periods before and after surgery were the same length as of each patient's surgery date. Demographic and clinical parameters were obtained, such as patient code, de-identified, age, sex, length of disease before surgery, presence of comorbidities, date of surgery, DBS target nucleus (STN), and hemisphere of implantation (unilateral or bilateral). Medication regimens used for anti-Parkinsonism treatment noted were levodopa/carbidopa, dopamine agonists, MAO-B inhibitors, COMT inhibitors, amantadine, and anticholinergics. Drug names, dosage, frequency, total of daily dose and total of medication were noted.

**Pharmacoeconomic Assessment**

The cost of expenditures was estimated using the prevailing prices of drugs in the retail market in Pakistan during the study period (November 2025 – February 2026). The prices were verified using the Maximum Retail Price (MRP) schedule given by Drug Regulatory Authority of Pakistan (DRAP) and at least two outlets of pharmacy. Generic prices were used where generic formulations predominated, whereas branded prices were used when applicable. All costs were estimated in Pakistani Rupees (PKR). Medication spending was reclassified into expenditure categories for analytical purposes, with expenditure on each category being added to the previous category. Category 1 represented PKR 10,000–30,000, Category 2 represented PKR 31,000–60,000, Category 3 represented PKR 61,000–90,000, Category 4 represented PKR 91,000–120,000, Category 5 represented PKR 121,000–150,000, Category 6 represented PKR 151,000–180,000, and Category 7 represented PKR 181,000–210,000. Medication cost scores were calculated using these expenditure categories, which were also used to compare the level of expenditure before and after surgery. The current

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pharmacoeconomic evaluation only considered the direct cost of anti-Parkinsonian drugs.

### 3. Statistical Analysis

All the collected data were summarized and analyzed using IBM SPSS Statistics Version 29 (IBM Corp., Armonk, NY, USA). The basic analytical unit was the individual patient and 12 month peri-operative interval. Two-tailed values of $p<0.05$ were regarded as being statistically significant. Demographic and clinical variables were summarized using descriptive statistics. Age, duration of disease, medication cost scores and number of medications were all quantified and expressed as Mean ± SD and range. Frequencies and percentages were used for categorical variables . The normality of the data was determined by the Shapiro–Wilk test prior to parametric analysis. Changes were reported as absolute mean difference as well as percentage change from baseline and 95% confidence intervals were computed when possible. Adverse events should be captured at a minimum.At least adverse events should be recorded.

All adverse event (AE) and adverse drug reaction (ADR) reported during the up to 180-day follow-up period after DBS surgery were recorded and evaluated. Structured data collection forms with specific descriptive fields were used for all reported events. Adverse events were classified by stimulation related, surgery related, device related, or medication related. All the events were described as transient or persistent. The Naranjo Adverse Drug Reaction Probability Scale (NARP) was used to formally assess and classify adverse drug reactions. Completed forms were checked by a trained clinical pharmacist before final data entry for accuracy, completeness, and clinical consistency.

### Ethical Considerations

The company called Danish international, Lahore approved the study (Approval Reference: PINS-IRB-2025/DBS-01). All subjects were provided with written informed consent for participation and information regarding the patient was kept confidential.

### Result

A total of 50 patients with Parkinson's disease who underwent bilateral subthalamic nucleus (STN) Deep Brain Stimulation (DBS) were included in the study. The age of the participants was 57.2 years (32 – 79 years), and most of the participants were male. Demographic and procedural parameters were analysed as a baseline to describe the study population and surgical profile. The significant reduction in pharmacological burden after surgery was seen as 88.0% of patients were able to have their medication reduced after DBS.

**TABLE 1. Patient and Procedure Characteristics**

| Variable | n (%) / Value |
|---|---|
| **Number of patients** | 50 |
| **Mean age, years (range)** | 57.2 (32–79) |
| **Sex** | |
| **Male** | 40 (80.0) |
| **Female** | 10 (20.0) |
| **Diagnosis** | |
| **Parkinson's disease (PD)** | 50 (100.0) |
| **Operated hemisphere** | |
| **Left** | 1 (2.0) |
| **Right** | 0 (0.0) |
| **Bilateral** | 49 (98.0) |
| **Targeted nucleus** | |
| **Subthalamic nucleus (STN)** | 50 (100.0) |
| **IPG implantation performed** | 50 (100.0) |

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| | |
|---|---|
| **Medication reduction achieved** | 44 (88.0) |

Demographic and procedural data of the study population are summarized in Table 1. The majority of the patients had bilateral STN-DBS, and Parkinson's disease was the only indication for STN-DBS in the study population. The medication reduction rate was high, indicating that DBS may be a key factor in reducing dependence on anti-Parkinsonian drugs.

During the 180-day follow-up, adverse events (AEs) were evaluated systematically in all enrolled patients. To describe the safety profile of DBS within the study population, the frequencies, timing, duration, and severity of adverse events were analysed, as were the severity and causality assessments.

**TABLE 2. Adverse Event Characteristics**

| Variable | n (%) |
|---|---|
| **Patients with adverse events** | 17 (34.0) |
| **Total adverse events recorded** | 17 |
| **Timing of adverse events** | |
| **Intraoperative** | 3 (6.0) |
| **Early postoperative (≤30 days)** | 10 (20.0) |
| **Late postoperative (>30 days)** | 4 (8.0) |
| **Duration of adverse events*** | |
| **Transient** | 14 (82.4) |
| **Persistent** | 3 (17.6) |
| **Stimulation-related causality assessment** | |
| **Probably related** | 17 (34.0) |
| **Possibly related** | 22 (44.0) |
| **Not related** | 11 (22.0) |
| **Surgery-related causality assessment** | |
| **Probably related** | 17 (34.0) |
| **Possibly related** | 21 (42.0) |
| **Not related** | 12 (24.0) |
| **Severity of adverse events** | |
| **Mild** | 9 (18.0) |
| **Moderate** | 7 (14.0) |
| **Severe** | 1 (2.0) |

Percentages shown for timing and severity of adverse events is the proportion of the total number of patients (n = 50). The percentages of event duration are reported as proportions of patients (n = 17) with adverse events. Some individual patients may have more than one adverse event and some individual adverse events may fall into more than one causality assessment category, which can result in a higher frequency of adverse events than the number of patients.Table 2 presents the frequency, type, and severity of adverse events observed after DBS surgery. Note: AE timing percentages are expressed as a proportion of the total cohort (n = 50); AE duration percentages (transient/persistent) are expressed as a proportion of patients who experienced any AE (n = 17); stimulation-related and surgery-related AE classifications represent Naranjo-style causality assessments across the full cohort and may exceed the number of AE patients as individual patients may have been assessed across multiple attribution categories; severity percentages are expressed as proportions of the total cohort (n = 50). Early postoperative adverse events were the most

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frequently recorded. The majority were transient and mild to moderate in severity, and no procedure-related mortality was observed. The overall safety profile of DBS was acceptable. Medication-related outcomes improved significantly after DBS surgery, and statistical analysis confirmed a significant decline in medication expenditure following the procedure ($p < 0.0001$).

To evaluate medication safety alongside economic outcomes, adverse drug reactions (ADRs) were systematically assessed using the Naranjo Adverse Drug Reaction Probability Scale. It is important to note that the Naranjo Algorithm was applied exclusively to medication-related adverse events; surgery-related and stimulation-related complications, which are not amenable to pharmacological causality assessment, were categorized and reported separately in Table 2. Table 3 presents the frequency of Naranjo-assessed ADR scores within the cohort. Adverse drug reactions were relatively infrequent, with the vast majority of patients navigating the post-operative period without any medication-attributable adverse reaction.

**Table 3. Frequency of Adverse Drug Reactions Assessed Using the Naranjo Scale**

| oAdverse Drug Reaction Status | n (%) |
|---|---|
| **ADR reported** | 8 (16.0) |
| **No ADR reported** | 42 (84.0) |
| **Total** | **50 (100.0)** |

This table shows the percentage and frequency of adverse drug reaction scores (ADRS) following DBS surgery. Adverse drug reactions were documented in 16.0% of patients (n = 8/50), while 84.0% of patients did not report any adverse drug reaction. Overall, adverse drug reactions were relatively infrequent in the study population.A comparison of medication cost outcomes between patients with and without adverse events demonstrated that medication costs decreased significantly after surgery. The occurrence of adverse events did not significantly affect postoperative medication reduction outcomes.

To determine whether post-operative complications hindered the financial and clinical efficacy of the procedure, healthcare utility metrics were stratified by patient safety outcomes. Table 4 demonstrates the comparative effect of the presence or absence of adverse events on post-surgical pharmaceutical expenditures. The statistical analysis yields a highly significant cost reduction across the cohort, proving that the occurrence of transient adverse events did not negatively influence the overall success of medication de-escalation.

**TABLE 4. Effect of Presence or Absence of Adverse Events on Outcomes**

| Outcome Measure | AE Present (Mean ± SD) | AE Absent (Mean ± SD) |
|---|---|---|
| **Postoperative medication expenditure category score** | 1.76 ± 1.71 | 1.91 ± 0.80 |

Table 4 demonstrates the relationship between adverse events and postoperative medication cost outcomes. A statistically significant reduction in medication cost was observed after DBS surgery ($p < 0.0001$, paired-samples t-test). The presence of adverse events did not significantly influence the achievement of medication reduction.

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Overall, the study findings demonstrate that DBS significantly reduced medication burden and medication-related costs among patients with Parkinson's disease. Although adverse events were recorded in 34.0% of patients, the majority were transient and did not significantly affect post-operative medication reduction outcomes or the overall pharmacoeconomic benefit of DBS.

## 4. Discussion

This current mixed retrospective–prospective pharmacoeconomic study showed that Deep Brain Stimulation (DBS) was linked to significant savings in medication use and direct medication costs for Parkinson's disease (PD) patients in Pakistan. A 88.0% of patients had reduced their medication use and 84.0% reduced their money spent on medication. These findings are similar to previous reports of a meaningful reduction in pharmacological burden after bilateral subthalamic nucleus (STN) DBS and reinforce the concept that DBS is a clinically effective and cost-effective treatment for advanced PD (Weaver et al., 2012; Ng et al., 2020; Khan et al., 2024). On a clinical level, the reported decrease in medication load is in the direction of and supported by data from randomized controlled trials and meta-analyses that reported substantial clinical improvements of motor symptoms, functional outcomes and quality of life after DBS (Deuschl et al., 2006; Schuepbach et al., 2013; Lachenmayer et al., 2021). The same results have been observed in Pakistan with the bilateral STN-DBS procedure where significant reduction in levodopa equivalent daily dose (LEDD) and improvement in motor performance has been reported in PD patients (Kalhoro & Hashim, 2023; Khan et al., 2024). In addition, expert consensus guidelines acknowledge DBS as a proven treatment for patients who have motor fluctuations and medication-related side effects which are not sufficiently controlled with medication alone (Bronstein et al., 2011). The economic results of this study are also consistent with the economic results reported in previous pharmacoeconomic studies. Previous research has shown that drug costs are substantially reduced over the long term after DBS, due to a reduction in drug dependence on anti-Parkinsonian medication (Tomaszewski & Holloway, 2001; Weaver et al., 2012). Likewise, Ng et al. (2020) reported that medication expenses were also reduced in follow-up after STN-DBS for a long period of time. In resource constrained health care systems like Pakistan, where OOH expenses are still high, savings for patients and their families in monthly health spending could be substantial due to reductions in the cost of medicines (Idrees et al., 2024). Safety profile in the current study was acceptable and adverse events occurred in 34.0% of patients, the majority of which were mild, moderate and transient. These results are consistent with earlier studies that showed that standardized AEM can improve the detection of adverse events, and does not necessarily impact on overall clinical effectiveness or quality of life (Burdick et al., 2010; Buhmann et al., 2017). Importantly, adverse events did not seem to affect the medication or economic effects that occurred after surgery. The therapeutic use of DBS is still growing with the introduction of new technologies in this field in the recent years. New research points to specific advances in the design of the electrodes, stimulation programming, and precision targeting that could further benefit the outcomes of treatment (Silver, n.d.; Yuan et al., 2023). Understanding of the biological mechanisms that underlie electrical brain stimulation (Van der Westhuizen et al., 2021) also has improved thanks to advances in neurotransmitter modulation and receptor signaling. Furthermore, new applications such as brain–computer interfaces (BCI) and other stimulation targets, represent further promising avenues for future study and development of movement disorder management and neurological rehabilitation (Lovejoy, 2023; Ortega-Robles et al., 2025; de Freitas et al., n.d.). There are a few caveats to be noted. This was an observational study at a single center, and used purposive sampling and a relatively short follow-up period, so may not be generalizable. In addition, no attempt was made to consider the wider economic costs, which encompass the burden on carers, hospitalisations costs, QALYs and device-related costs. However, the importance of continuous safety evaluation and long-term monitoring cannot be overlooked for future research and decision-making in healthcare (Bole et al., 2026).

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## 5. Conclusion

This study aimed to assess the pharmacoeconomic burden of Deep Brain Stimulation (DBS) on the use of medications, expenditure of medications and adverse event profiles of patients with Parkinson's disease (PD) in Pakistan. The results showed significant decreases in medication burden and medication expenditure category scores, with reductions in medication in 88.0% of the patients and in 84.0% of the total study population, respectively. In addition, adverse events were reported in a small number of patients, and were mostly short-lived and mild to moderate in severity, with fewers than were reported to be medication-related adverse drug reactions. The results indicate that DBS could be a component in decreasing the amount of medications used in patients with advanced Parkinson's disease who have been carefully screened. The findings, however, should be considered within the context of the study's limitations such as the single-center, observational design, lack of control group, limited length of follow-up, and limited economic evaluation to direct out-of-pocket costs for medications. Future multicenter studies with standardized disease severity measures, quality-of-life assessments, and comprehensive economic evaluations and longer follow-up are warranted to further characterize the long-term clinical and pharmacoeconomic implications of DBS in low- and middle-income healthcare settings.

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