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# Revisiting eligibility for deep brain stimulation: Do preoperative mood symptoms predict outcomes in Parkinson's disease patients?

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ABSTRACT

*Introduction:* Anxiety and depression are common in PD, occurring in an estimated 30%–40% of PD patients. However, the extent to which these emotional symptoms interfere with Deep Brain Stimulation (DBS) outcomes is not well established. This study examined the association between pre-operative emotional well-being and postsurgical cognitive, emotional, and motor performance in PD.

*Methods:* Forty-nine PD patients underwent neurological, neuropsychological (global cognition, processing speed, language, visuospatial, memory), and emotional assessments pre- and post-DBS. Fifteen patients were administered the UPDRS. Patients were divided into Anxious (Anx; n = 21), Comorbid Anxious and Depressed (Anx + Dep; n = 15), and Emotionally Asymptomatic (EA; n = 13) based on BAI and BDI-II cutoffs, and compared on pre-post changes in neurocognitive, mood, and motor scores using analyses of covariance (ANCOVA), controlling for education, ethnicity, and disease duration.

*Results:* Pre-DBS, there were no significant differences between the three groups on any neuropsychological measure. Overall change from pre-to post-DBS revealed declines on multiple cognitive measures and lower symptom endorsement on the BAI among all participants. No group differences were observed on neurocognitive measures, mood, or UPDRS.

*Conclusions:* PD patients with mild-moderate anxiety or comorbid anxiety/depression pre-DBS do not show greater cognitive, emotional, and motor changes post-DBS compared to emotionally asymptomatic patients. These data emphasize the importance of discussing potential DBS outcomes, while keeping in mind that psychiatric comorbidity should not necessarily exclude patients from DBS. The notion that premorbid mood symptoms could disqualify a candidate for surgery would be a disservice, as this group performs comparably to asymptomatic peers.

## 1. Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disorder, affecting 1% of the population over age 60 [1]. An estimated 20–57% of PD patients experience mild cognitive impairment within the first three to five years after diagnosis [2,3], characterized by impairments in verbal fluency, attention, processing speed, executive function, and visuospatial skills [4,5]. Mood disorders are also highly prevalent and remain among the top five complaints in early and advanced PD patients [6]. Estimated prevalence for anxiety or depression individually range from 30 to 40% [7,8]. There is also significant comorbidity between anxiety and depression: 92% of patients with an anxiety disorder also had a depressive disorder or symptoms [9].

Deep Brain Stimulation (DBS) surgery provides significant improvement in motor symptoms and quality of life [10][ 11]. While it is well-established that DBS ameliorates motor symptoms [12], postsurgical DBS follow up studies reveal a different picture for cognition, that may include decreased performance on tasks of verbal fluency, processing speed, working memory and executive function [11,13]. Postsurgical mood outcome studies are mixed: Some studies show improvement in depression [4,12,14–17] and anxiety symptoms [17], while others show either worsening or no change in symptomology [14,18–20].

One question that remains unresolved is whether PD related presurgical mood symptoms impact postsurgical mood outcomes. In one study examining 50 PD patients, those with a positive screen for depression prior to surgery showed improved depressive symptoms six months postoperatively, including those who did not screen positive for

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depression at baseline [12]. In another study, 50% of patients with a history of psychiatric disorders such as depression and/or mania improved post DBS [21]. Okun and colleagues found that PD patients with a preoperative history of depression had significantly higher depression scores post DBS and had less motor improvement following surgery than their non-depressed counterparts [18]. Depression is also considered the most common psychiatric event after DBS, and patients with inadequately controlled depression are usually not considered for surgery because DBS has the potential to exacerbate pre-surgical mood [22].With regard to the influence of baseline mood symptoms on motor and cognitive function, Ng and colleagues [23] found that baseline depression prior to surgery was associated with significant worsening of motor symptoms post DBS and that those with higher levels of depression pre DBS had poorer cognitive function postsurgically, though this was not statistically significant [23]. Emerging evidence appears to suggest that mood symptoms are critical determinants of PD prognosis, as anxiety and depression were the strongest predictors of longitudinal decline on measures of both verbal and visual learning, above other clinical and demographic factors [24]. This makes an awareness of presurgical mood disturbance critical for decision making regarding DBS candidacy.

Therefore, the primary aim of this study is to evaluate whether presurgical anxiety or comorbid anxiety/depression symptoms are associated with neuropsychological, emotional, and motor changes following DBS in a community-based sample of patients with idiopathic PD.

## 2. Methods

### 2.1. Participants

A retrospective database review was performed of the Movement Disorders Clinic at the University of Miami (UM) Miller School of Medicine DBS candidates from 2000 to 2010. All participants underwent pre- and post-surgical evaluations, which included a neurologic examination by a movement disorders specialist as well as a clinical interview and comprehensive neuropsychological testing by a neuropsychologist. Our multidisciplinary DBS conference discussed all potential candidates to determine their suitability for DBS. Patients were considered good candidates for DBS if they had severe motor symptoms despite optimal pharmacotherapy, responsiveness to levodopa, and no surgical contraindications. Suicidal ideation was assessed during the clinical interview, and no participants endorsed suicidal ideation or intent preoperatively. For a subset of the sample, pre- and post-surgical Unified Parkinson's Disease Rating Scale (UPDRS) ratings were available.

All participants met diagnostic criteria for idiopathic PD based on UK PD Brain Bank Criteria [25]. None had been diagnosed with (1) a comorbid movement or neurodegenerative disorder other than PD, (2) moderate to severe dementia, (3) history of substance abuse, or (4) current or history of severe mental illness (i.e., Bipolar Disorder, Schizophrenia, Schizoaffective Disorder, psychosis). This information was gathered during clinical interviews with a neurologist and/or neuropsychologist and was corroborated through electronic medical record review.

Of the initial 54 PD patients examined, five were excluded due to a history of substance abuse or moderate dementia. The study sample therefore consisted of 49 participants: 75.5% (37) male, mean age of 63.8 ± 8.3 years and mean education of 13.2 ± 4.2 years. Fifty-three percent (n = 26) were Hispanic, of which 85% (n = 22) were Spanish-speaking monolingual. On average, the participants had 9.5 ± 4.8 years of disease duration. All but one patient (97.9%) underwent subthalamic nucleus (STN) DBS; the other patient's DBS target was the internal segment of the globus pallidus (GPi). Participants were categorized into three groups based on the severity of their emotional symptoms at presurgical evaluation and established clinical cut-offs for depression and anxiety using the BDI-II and BAI, respectively: Anxious Only (Anx), Comorbid Anxious and Depressed (Anx + Dep), and Emotionally Asymptomatic (EA). The Anx group was identified by those scoring above 10 on the BAI and below 14 on the BDI-II. The Anx + Dep group included patients who scored 14 or above on the BDI-II and 10 or more on the BAI. The EA group included patients who scored below these cut-offs on both measures.

### 2.2. Procedures and data collection

All study procedures were approved by the UM Miller School of Medicine Institutional Review Board. Each patient was evaluated twice by a movement disorder specialist in the Department of Neurology and a neuropsychologist in the Division of Neuropsychology in their primary language [English (n = 27) or Spanish (n = 22)]. All DBS surgeries were completed within one year of pre-evaluation, with a mean time of five months. Follow-up evaluations were completed on average within two years post-operatively. There were no significant differences among the groups regarding time since surgery (See Table 2 for results).

### 2.3. Measures

The neuropsychological battery was comprised of tests known to be clinically sensitive to cognition in PD with established reliability and validity [26,27]. This battery included a general screen (Mini Mental State Exam), and measures of processing speed (Symbol Digit Modalities Test [SDMT]), word retrieval (Boston Naming Test [BNT]), verbal fluency (Controlled Oral Word-Association Test [FAS/PTM and Animals]), visual spatial skills (Judgment of Line Orientation Test [JLO, 15-item version]), and verbal learning and memory (California Verbal Learning Test- Second Edition [CVLT-II]).

The motor scale of the UPDRS was administered both on and off dopaminergic medications prior to DBS, and on and off electrical stimulation following DBS surgery. As described above, the BDI-II and BAI assessed depression and anxiety symptoms [27], respectively.

### 2.4. Statistical analyses

Preliminary examination of group differences among clinically relevant covariates (i.e., age at both evaluations, years of education, gender, ethnicity, years of disease progression, time since surgery, and motor scale scores off medications) were tested using analyses of variance (ANOVA) and chi square tests of independence ($X^2$) where appropriate. Findings revealed significant group differences in years of education [F (2, 46) = 6.967, p = 0.002], ethnicity [$X^2(2) = 7.66$, $p = 0.022$], and disease duration (years) [F (2, 45) = 3.903, p = 0.027]. For review, see Table 1 for descriptive statistics on these measures for each group independently. As such, these measures were included as a covariate in the subsequent main analyses.

Paired sample t-tests comparing pre- and post-DBS surgery performance on the cognitive, emotional and motor scores were carried out on the overall sample. ANOVAs were run to evaluate potential group differences due to psychotropic medication use. Analysis of covariance (ANCOVAs) were employed, with mood group as the fixed factor and years of education, ethnicity, and disease duration as covariates to examine pre-DBS group difference. To test whether pre to post DBS changes were significantly different between the Anx + Dep, Anx, and EA groups, additional ANCOVAs were run on change scores (Time 2 – Time 1) for all neurocognitive tests, mood questionnaire scores and motor rating scales, with mood group as the primary independent variable, controlling for years of education, ethnicity, and disease duration.

## 3. Results

Of the 49 participants, 21 met criteria for the Anx group

**Table 1**
Demographic information, disease characteristics, and raw scores from neurocognitive assessments for each group at the pre-surgical evaluation. Data are means ± SD or frequencies, as appropriate.

| | Emotionally asymptomatic (n = 13) | Anxious Only (n = 21) | Anxious + Depressed (n = 15) | Overall Sample (n = 49) | p |
|---|---|---|---|---|---|
| **Demographics** | | | | | |
| Age, years | 63.4 ± 9.5 | 64.1 ± 7.8 | 63.5 ± 8.3 | 63.7 ± 8.3 | 0.967 |
| Education, years | 15.5 ± 4.1 | 13.9 ± 2.6 | 10.4 ± 4.7 | 13.2 ± 4.2 | **0.002*** |
| Gender (male/female), n | 9/4 | 16/5 | 12/3 | 37/12 | 0.800 |
| Ethnicity (Hisp/Non-hisp), n | 7/6 | 7/14 | 12/3 | 26/23 | **0.022*** |
| **Clinical Information** | | | | | |
| Disease duration, years | 11.3 ± 4.9 | 7.3 ± 4.2 | 10.7 ± 4.6 | 9.5 ± 4.8 | **0.027*** |
| Disease severity, UPDRS off Psychotropic Medication Use (Yes/No), n | 48.2 ± 17.6 3/6 | 50.7 ± 5.9 9/11 | 38.0 ± 9.9 5/6 | 44.8 ± 12.9 17/23 | 0.251 |
| **Pre-surgical Neurocognitive Assessments** | | | | | |
| **Global cognition** | | | | | |
| MMSE | 28.3 ± 1.6 | 28.2 ± 1.5 | 27.1 ± 2.7 | 27.8 ± 1.9 | 0.825 |
| **Processing Speed** | | | | | |
| SDMT | 32.8 ± 9.5 | 32.0 ± 11.5 | 22.6 ± 13.4 | 29.2 ± 12.3 | 0.614 |
| **Language** | | | | | |
| BNT | 48.8 ± 6.1 | 50.2 ± 7.4 | 39.7 ± 12.0 | 46.6 ± 9.9 | 0.310 |
| COWAT- Animals | 17.0 ± 4.7 | 16.5 ± 5.4 | 14.5 ± 4.9 | 16.0 ± 5.1 | 0.909 |
| COWAT-FAS/PTM | 35.7 ± 12.1 | 37.3 ± 12.6 | 29.5 ± 14.9 | 34.4 ± 13.4 | 0.757 |
| **Visuospatial Skills** | | | | | |
| JLO | 11.3 ± 3.3 | 10.2 ± 3.3 | 9.1 ± 2.1 | 10.1 ± 3.0 | 0.106 |
| **Memory** | | | | | |
| CVLT-II Trials 1-5 | 37.5 ± 11.2 | 38.7 ± 9.2 | 36.2 ± 7.1 | 37.7 ± 9.2 | 0.971 |
| CVLT-II Short Delay Free Recall | 7.0 ± 3.8 | 6.6 ± 2.1 | 6.1 ± 1.7 | 6.6 ± 2.6 | 0.571 |
| CVLT-II Long Delay Free Recall | 6.7 ± 3.7 | 7.4 ± 2.3 | 6.1 ± 2.9 | 6.8 ± 2.9 | 0.511 |
| **Emotional Functioning** | | | | | |
| BDI-II | 6.2 ± 3.7 | 8.8 ± 3.5 | 21.7 ± 5.4 | 12.1 ± 7.7 | 0.000* |
| BAI | 5.6 ± 3.0 | 17.6 ± 6.3 | 24.7 ± 9.5 | 16.4 ± 9.9 | 0.000* |

UPDRS = Unified Parkinson's Disease Rating Scale; MMSE = Mini-Mental State Examination; SDMT = Symbol Digit Modalities Test; BNT = Boston Naming Test; COWAT-Animals = Controlled Oral Word Association Test- Animals; COWAT-FAS/PTM = Controlled Oral Word Association Test- Phonemic; JLO = Judgement of Line Orientation; CVLT-II = California Verbal Learning Test- Second Edition; BDI-II = Beck Depression Inventory- Second Edition; BAI = Beck Anxiety Inventory. *p ≤ 0.05.

(BAI = 17.6 ± 6.3; BDI = 8.8 ± 3.5), 15 for the Anx + Dep (BDI = 21.7 ± 5.4; BAI = 24.7 ± 9.5) and 13 for the EA (BDI = 6.2 ± 3.7; BAI = 5.6 ± 3.0). A subset of 15 patients had a mean score of 44.8 ± 12.9 points on the UPDRS when off medication prior to DBS. Table 1 shows additional disease characteristics, psychotropic medication use, and neurocognitive scores for these groups. Of the combined 36 patients in the Anx Only and Anx + Depressed groups, only 14 were on psychotropic medications; medication use for five patients was not available. As shown, the Anx group self-rated mild to moderate symptoms whereas the Anx + Dep group endorsed moderate severity.

In the overall sample, comparisons of pre to post DBS surgery on cognitive measures showed significant ($p < 0.05$) declines in MMSE (Cohen's ($d_z$) = 0.36), SDMT ($d_z = 0.36$), COWAT Animals ($d_z = 0.33$), COWAT FAS/PTM ($d_z = 0.91$), and CVLT-II Trials 1–5 ($d_z = 0.34$) performance. Following surgery, participants reported significantly less symptoms of anxiety on the BAI ($d_z = 0.56$) and demonstrated fewer PD motor symptoms when off medications (UPDRS off; $d_z = 1.20$). Changes from pre to post DBS surgery were non-significant among all other measures (see Table 3). Similarly, no differences were observed pre to post DBS between patients on vs. off psychotropic medications on any cognitive domain, mood inventory, or motor score. When the DBS sample was subdivided into those with Anx + Dep, Anx only, and EA, there were no significant differences on any neurocognitive measure pre DBS. ANCOVA results also revealed no significant differences between the groups on any neurocognitive, motor, or mood change score from pre to post DBS surgery. (See Table 2).

## 4. Discussion

Depression and anxiety are the two most frequently reported mood alterations associated with PD [7,8]. The assessment of mood state is often included as part of the DBS screening battery and factored into the decision-making process when evaluating candidacy for surgery [18,22]. Patients with untreated depression or severe anxiety are often considered poor candidates for surgery and offered nonsurgical therapies [22]. The present study investigated whether presurgical mood symptoms, ranging from mild to moderate degrees of severity as measured by self-reported symptoms of depression and anxiety, were associated with DBS postsurgical outcomes. With regard to cognition, our sample as a whole demonstrated diminished cognitive performance post DBS with regard to the mental status screen as well as lower scores on tasks of processing speed, verbal fluency, and verbal learning. These findings are consistent with previous studies examining the effects of DBS on cognition [5,11,13,19]. However, without a no-DBS control group, and without controlling for time interval between testing, we cannot fully determine whether these effects are a result of the DBS surgery or represent expected changes in PD over time. When the groups were divided based on presurgical mood symptomatology (Anx, Anx + Dep, EA), they did not differ significantly in their change score in any cognitive domain. Additionally, we found that for a smaller subset of patients (n = 15) where pre and post motor ratings were

**Table 2**
Follow-up clinical information, neurocognitive assessment, mood measures, and motor scale change scores. Data are means ± SD or frequencies, as appropriate.

| | Emotionally Asymptomatic (n = 13) | Anxious Only (n = 21) | Anxious + Depressed (n = 15) | p |
|---|---|---|---|---|
| **Clinical Information** | | | | |
| Age at follow-up, years | 64.8 ± 9.4 | 66.1 ± 8.3 | 65.8 ± 7.8 | 0.915 |
| Time since surgery, years | 2.1 ± 1.3 | 2.3 ± 1.8 | 2.6 ± 1.1 | 0.634 |
| Site of DBS (STN/GPI), n | 14/0 | 25/0 | 14/1 | |
| Side of implantation (R/L/BL), n | 0/4/10 | 3/8/13 | 5/3/7 | |
| **Neurocognitive Assessments Change Scores (n)** | | | | |
| MMSE | 0.0 ± 1.4 | −0.7 ± 1.6 | −1.7 ± 3.2 | 0.445 |
| SDMT | −4.8 ± 6.2 | −1.3 ± 9.9 | −5.1 ± 10.9 | 0.214 |
| BNT | 0.8 ± 2.6 | −1.1 ± 2.7 | −1.3 ± 8.0 | 0.476 |
| COWAT- Animals | −1.1 ± 6.2 | −1.7 ± 4.2 | −1.7 ± 3.6 | 0.376 |
| COWAT-FAS/PTM | −5.3 ± 10.7 | −9.7 ± 7.1 | −8.9 ± 8.9 | 0.228 |
| JLO | 0.8 ± 5.2 | 1.0 ± 3.5 | 0.5 ± 2.4 | 0.341 |
| CVLT-II Trials 1-5 | −0.6 ± 7.5 | −3.7 ± 9.1 | −4.7 ± 7.4 | 0.782 |
| CVLT-II Short Delay Free Recall | −0.2 ± 3.2 | 0.0 ± 2.9 | −1.5 ± 3.1 | 0.707 |
| CVLT-II Long Delay Free Recall | −0.1 ± 2.9 | −0.2 ± 3.4 | −0.9 ± 2.2 | 0.866 |
| **Mood Measures Change Scores** | | | | |
| BDI-II | −1.2 ± 4.8 | 2.7 ± 9.2 | −4.9 ± 7.9 | 0.281 |
| BAI | −2.4 ± 5.1 | −5.6 ± 8.4 | −4.6 ± 9.3 | 0.308 |
| **Motor Scale Change Score** | (n = 5) | (n = 4) | (n = 6) | |
| UPDRS, score (n) | −28.6 ± 15.4 | −37.5 ± 6.4 | −20.3 ± 23.0 | 0.727 |

STN = Subthalamic nucleus; GPI = Globus pallidus interna; MMSE = Mini-Mental State Examination; SDMT = Symbol Digit Modalities Test; BNT = Boston Naming Test; COWAT-Animals = Controlled Oral Word Association Test- Animals; COWAT-FAS/PTM = Controlled Oral Word Association Test- Phonemic; JLO = Judgement of Line Orientation; CVLT-II = California Verbal Learning Test- Second Edition; BDI-II = Beck Depression Inventory- Second Edition; BAI = Beck Anxiety Inventory; UPDRS = Unified Parkinson's Disease Rating Scale.
*p ≤ 0.05.

available, presurgical mood symptoms were not associated with changes in motor outcomes post DBS. The three groups did not differ in terms of age, gender, or handedness. Though education, ethnicity, and disease duration differed between the groups, this was statistically controlled for in our analyses. Thus, the absence of observed differences in cognitive and mood scores was likely not attributable to demographic inequalities among the groups.

This study examined individuals who were emotionally symptomatic pre-operatively, ranging mostly from mild to moderate severity, compared to those who were not emotionally symptomatic. Our sample is different from previous studies [12,18] that have focused on individuals whose mood symptoms are effectively treated prior to surgery and do not meet clinically significant levels of anxiety or depression at the time of intervention. Our study is the first to show that the presence of anxiety, or comorbid anxiety and depressive symptoms at the time of DBS surgery is not associated with changes in cognition and mood following DBS. Further, it is unlikely that psychotropic medication explains this finding, as there were no significant differences between participants taking medication and those who were not on medication, pre-to post-DBS. This finding is noteworthy as patients who consistently show depressive symptoms are usually routinely assessed as weaker candidates for DBS consideration [28]. Based on our study, the notion that preoperative mood symptoms could weaken or disqualify a candidate for surgery would be a disservice as this group performs comparably to their asymptomatic peers. Our data are consistent with studies demonstrating no significant worsening of depression [20] and anxiety [4,14,20] post-surgery. Kaiser and colleagues reported no worsening in mood and psychosocial functioning three years after DBS, as long-term mood outcomes were not affected by pre-surgical mood symptom severity [29]. Therefore, our study provides further evidence that at least for some PD patients, a history of mood comorbidity does not put them at greater risk of experiencing either greater emotional or

**Table 3**
Results and descriptive statistics of paired sample t-tests evaluating differences between pre- and post-DBS surgery scores on all measures.

| Measure | Pre-Surgery *M* ± *SD* | Post-Surgery *M* ± *SD* | *t* | *p*-value | Cohen's $d_z$ |
|---|---|---|---|---|---|
| MMSE | 27.88 ± 1.97 | 27.08 ± 3.31 | 2.47 | .017* | .36 |
| SDMT | 30.74 ± 12.43 | 27.41 ± 14.07 | 2.08 | .045* | .36 |
| BNT | 46.60 ± 9.90 | 46.04 ± 10.82 | 0.77 | .443 | .11 |
| Animals | 16.02 ± 5.10 | 14.51 ± 4.62 | 2.31 | .025* | .33 |
| FAS or PTM | 34.44 ± 13.41 | 26.54 ± 12.80 | 6.34 | < .001* | .91 |
| JLO | 10.43 ± 2.78 | 10.45 ± 2.82 | −0.06 | .952 | .01 |
| CVLT-II Trials 1-5 | 37.66 ± 9.21 | 34.84 ± 11.07 | 2.28 | .028* | .34 |
| CVLT-II SD FR | 6.59 ± 2.60 | 6.14 ± 3.32 | 1.00 | .322 | .19 |
| CVLT-II LD FR | 6.84 ± 2.96 | 6.49 ± 3.69 | 0.79 | .434 | .12 |
| BDI-II | 12.06 ± 7.73 | 11.43 ± 8.69 | 0.53 | .599 | .08 |
| BAI | 16.30 ± 10.03 | 11.91 ± 10.08 | 3.82 | < .001* | .56 |
| UPDRS (on) | 19.50 ± 8.05 | 17.30 ± 7.80 | 0.56 | .590 | .18 |
| UPDRS (off) | 47.71 ± 15.05 | 23.43 ± 11.25 | 3.18 | .019* | 1.20 |

*p ≤ 0.05.

cognitive adverse outcomes following DBS [21]. Since these PD patients can safely respond to DBS with no greater risk, receiving social support before and after surgery rather than being excluded from surgery is important when assessing for candidacy [29].

In addition, these results indicate an overall trend towards improved mood symptoms following surgery, as shown by twice the number of emotionally asymptomatic participants post study compared to pre-study self-ratings. The most dramatic decline, from 42% to 16%, was observed among those reporting anxiety symptoms in the absence of depression. Given that several items on the BAI have a motor component, decrease in scores post-surgically may reflect improved motor function, rather than decreases in anxiety alone. Regardless of the etiology, this reduction in self-rated mood symptoms post-DBS provides further evidence that pre-surgical mood should not serve to exclude patients from surgery, particularly in light of the fact that so many participants no longer met criteria for clinical depression or anxiety following DBS.

Overall, this study has several strengths and some limitations. Strengths include the pre and post assessment using a comprehensive cognitive and mood battery, the novel exploration of comorbid mood symptomatology present at the time of surgery on postsurgical outcomes, comprehensive and interdisciplinary DBS team screening (i.e., neurologist, neurosurgeon, neuropsychologist), and the inclusion of a multicultural sample. Limitations include the relatively small sample size, lack of availability of UPDRS scores in all patients, and lack of uniform follow up time from pre to post-surgical assessment. Our sample included a preponderance of participants with mild to moderate mood symptoms and therefore these findings cannot be generalized to those with more severe psychiatric symptomatology. Follow up was limited to one point in time and fixed follow-up time points would have helped to better characterize the trajectory of cognitive and emotional changes following surgery. Also, the absence of a depression-only group in our study makes it difficult to assess the relationship of depression only on postsurgical mood, cognition, and motor function changes. Finally, given the small number of patients on psychotropic treatment in the Anxiety and Comorbid Anxiety + Depression groups, the influence of combined antidepressants and anxiolytics on DBS outcomes could not be studied; 38.88% (14/36) of patients with elevated mood at the time of DBS were treated with psychotropic medications. Future studies should address the limitations described above (i.e., larger sample size, UPDRS on all patients, division of groups based on symptom severity, standard post DBS follow-up, inclusion of depression only group, assessment of psychotropic medication use and dosage).

The safety of DBS is first and foremost of clinical importance when evaluating the therapeutic benefit for PD [16,17]. The goal of a neuropsychological evaluation is therefore to assist in the assessment of cognition and mood to determine DBS candidacy, to help predict which individuals may be at increased risk for negative outcomes following stimulation, and to inform the decision-making process. Depression and anxiety remain underdiagnosed and undertreated in those with PD [6]. To date there are no clear recommendations regarding the diagnosis of anxiety in PD, though there are a few recommendations for depression in PD including the use of validated tools to be used in combination with a clinical interview and collateral information from caregivers [30]. Our findings emphasize the importance of physicians discussing potential outcomes with the DBS candidate prior to surgery, while keeping in mind that psychiatric comorbidity should not necessarily exclude patients from undergoing DBS. Our study also has implications for educating treatment providers that may be currently determining eligibility for DBS based on the presence of anxiety and/or depression. A better approach may be to assess specific symptoms (i.e., suicidal thoughts, anger, panic attacks) and to use a standardized risk factor checklist, rather than self-report measures alone to assess DBS candidacy. Postoperative mood symptoms should be appropriately followed and managed, and included as part of a routine follow-up of potential risks and benefits of surgery, which varies patient by patient. Although our study did not find that comorbid mood disturbances are associated with worse cognitive, mood, or motor outcomes, movement disorder teams are highly encouraged to continue to identify preoperative mood status in all PD patients considering DBS.

## 5. Conclusion

The present study provides important data showing preoperative mood symptoms, characterized by mild to moderate anxiety and comorbid anxiety and depression are not necessarily associated with negative post DBS cognitive, emotional, and motor outcomes. Rather, PD patients with mild to moderate mood symptoms show the same benefits as their emotionally asymptomatic counterparts. These data demonstrate the need for a formal diagnostic interview of mood symptoms so prospective patients, their families, and the surgical team can utilize this information to assist in the decision-making process when weighing the risk and benefits when considering whether or not to proceed with surgery.

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