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Unilateral subthalamic nucleus deep brain stimulation improves sleep quality in Parkinson's disease

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Abstract

Background—Sleep disturbances are common in Parkinson's disease (PD). Bilateral subthalamic nucleus (STN) deep brain stimulation (DBS) is superior to best medical therapy in the treatment of motor symptoms in advanced PD, and observational studies suggest that bilateral STN DBS improves sleep in these patients as well. Unilateral STN DBS also improves motor function in PD, but its effects on sleep have not been extensively investigated.

Methods—We report the effects of unilateral STN DBS on subjective sleep quality as measured by the Pittsburgh Sleep Quality Index (PSQI) in 53 consecutive PD patients. These subjects completed the PSQI prior to surgery and at 3 and 6 months post-operatively. The primary outcome measure was the change in the global PSQI at 6 months post-operatively versus the preoperative baseline, measured with repeated measures analysis of variance (ANOVA).

Results—Patients with PD who underwent unilateral STN DBS had a significant improvement in PSQI at 6 months post-operatively (baseline 9.30 ± 0.56 (mean $\pm$ SEM), 6 months: 7.93 ± 0.56 , $p=0.013$). Supplemental analyses showed that subjects selected for STN DBS placed on the right had worse baseline subjective sleep quality and more improvement in PSQI at 6 months compared to patients who received left STN DBS.

Conclusion—This prospective case series study provides evidence that unilateral STN DBS improves subjective sleep quality in patients with PD at up to 6 months postoperatively as measured by the PSQI.

Keywords

Parkinson's disease; sleep; subthalamic nucleus; deep brain stimulation; non-motor symptom

Introduction

Bradykinesia, rigidity, tremor, and postural instability constitute the cardinal symptoms of Parkinson's disease (PD), yet non-motor features of the disease are often more problematic

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and disabling[1, 2]. Sleep disturbances are particularly common in PD, affecting 74–98%[3, 4] of patients. Multiple aspects of sleep are affected, resulting in insomnia, difficulty rolling over in bed, frequent and early awakenings, nocturia, nocturnal motor fluctuations, excessive daytime sleepiness (EDS) and altered dream content, including vivid dreams or nightmares and REM sleep behavior disorder[2, 4, 5]. Polysomnographic studies have shown reduced sleep time, reduced time spent in both REM and slow wave sleep, and poor sleep efficiency in PD patients compared to controls[2]. Because of the prevalence and severity of sleep disorders in PD, it is important to understand how currently available treatment strategies influence sleep quality.

Unilateral and bilateral deep brain stimulation (DBS) of the subthalamic nucleus (STN) improve motor function and decrease motor fluctuations in patients with moderate to advanced PD[6–9]. Improvement in quality of life measures and activities of daily living has been described following bilateral STN DBS and at up to 1 year postoperatively in patients with unilateral STN DBS[6–8]. Although bilateral STN DBS provides greater motor benefit than unilateral DBS[10, 11], the unilateral approach may avoid some potential side effects of the bilateral procedure, including worsening of dysarthria, dysphagia, and cognitive dysfunction[8, 10, 12]. Additionally, compared to bilateral surgery, the unilateral STN DBS surgery is shorter in duration. Furthermore, the motor symptoms of PD are often asymmetric and responsive to medications, and unilateral STN DBS may be preferable for many patients, particularly considering that the option for contralateral surgery is still available later, if needed.

Several groups have evaluated the effects of bilateral STN DBS on sleep in patients with PD, showing both subjective and polysomnographic (PSG) evidence of improvement in sleep after the procedure. These include improvements in sleep quality, total sleep time, REM sleep, deep slow wave sleep, sleep efficiency, early morning dystonia, and nocturnal mobility[13–18]. One group has also reported an improvement in subjective sleep quality and daytime sleepiness in a combined group of 17 patients after unilateral or bilateral STN DBS, of whom 12 had unilateral STN DBS[19]. In the present study, we evaluate subjective sleep quality in 53 PD patients pre-operatively and at 3 and 6 months after unilateral STN DBS.

Methods

Patient Demographics

Patient selection for STN DBS has been previously described in detail[20]. All subjects underwent pre-operative screening with neuropsychiatric evaluation and brain MRI. Patients with dementia, active depression (i.e. uncontrolled on medications), psychosis, significant cortical or subcortical atrophy, or marked ischemic changes on MRI were not candidates for DBS. Target localization involved frame-based stereotaxy, microelectrode recordings, and intra-operative assessment of DBS stimulation effects, as previously described[8]. Post-operative MRI was obtained within 24 hours in all cases to confirm accurate lead placement and assess for potential complications. Eighty-nine consecutive patients who underwent successful unilateral STN DBS for Parkinson's disease (UK Brain Bank criteria[21]) at the University of Alabama at Birmingham between March 2004 and December 2008 were evaluated. Notably, patients meeting criteria for STN DBS at our center always undergo the unilateral procedure, and subsequently have the contralateral surgery in a staged manner, if needed. Patients who required a second surgery prior to 6 months after the initial stimulator placement and patients without complete follow-up evaluations at 3 and 6 months were excluded from the analysis. Fifty-three patients were included in the final analysis (Figure 1). The electrode was placed contralateral to the most severely affected side in all cases. Twenty-eight of the 53 patients (52.8%) underwent surgery on the left STN. Sixty-two

percent of the patients were male. The mean patient age at the time of surgery was 60.5 ± 9.5 years (mean $\pm$ SD) with a range of 37–76 years, and the mean duration of disease was 11.6 ± 5.5 years with a range of 2.8–30.1 years. Mean stimulation parameters 6 months postoperatively were: pulse width 84.91 ± 26.79 μ sec (mean $\pm$ SD), frequency 158.87 ± 14.60 hertz, and amplitude 3.34 ± 0.57 volts. In subjects who underwent STN DBS on the right, 64% were male, mean age was 59 ± 9.9 (range 37–74), and mean duration of disease was 11.8 ± 5.9 (range 2.8–24.9 years). Mean stimulation parameters at 6 months postoperatively were: pulse width 82.8 ± 26.38 μ sec, frequency 156.6 ± 11.15 hertz, and amplitude 3.46 ± 0.45 volts. Of subjects who underwent STN DBS on the left, 60.7% were male, mean age was 62 ± 9.0 (range 43–76), and mean duration of disease was 11.5 ± 5.3 (range 3.8–30.1 years). Mean stimulation parameters at 6 months post-operatively were: pulse width 86.8 ± 27.49 μ sec, frequency 160.9 ± 17.05 hertz, and amplitude 3.22 ± 0.65 volts. There was no significant difference in gender, age, duration of disease, or stimulation parameters between subjects who underwent surgery on the right and those who underwent surgery on the left. The study was approved by the Institutional Review Board (IRB) of the University of Alabama at Birmingham. The IRB approved a waiver of consent for collection of these data as part of routine clinical care and quality control.

Patient evaluation

Patients prospectively completed the Pittsburgh Sleep Quality Index (PSQI) questionnaire at the preoperative baseline and at 3 and 6 months postoperatively. The PSQI is a validated subjective measure of sleep quality over a 1 month time period with subscores that evaluate sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleep medications, and daytime dysfunction[22]. These subscores are combined to establish a global PSQI score. Each subscale score is converted to a value between 0–3, with 3 representing the greatest sleep impairment. The global PSQI range is 0–21, with 21 representing the worst sleep quality.

Patients were also evaluated with the Unified Parkinson's Disease Rating Scale (UPDRS[23] part III in the "practically defined off" medication state[24] at the preoperative baseline evaluation and at 3 and 6 months postoperatively off medications with the stimulator on. In addition, subjects completed the Parkinson's Disease Questionnaire-39[25] (PDQ-39) at each timepoint to evaluate quality of life. The PDQ-39 is a validated measure composed of 39 questions that are reported as 8 separate scales (mobility, activities of daily living, emotional well being, stigma, social support, cognition, communication, and bodily discomfort). The scales are combined to calculate the PDQ-39 Summary Index. The summary index and each scale are calculated to have a range of 0 (no problem) to 100 (worst dysfunction). Changes in dopaminergic medication doses over time were evaluated by calculation of levodopa equivalent dose (LED) in the following manner: 100 mg dose of levodopa was defined as equivalent to 133 mg of controlled-release levodopa; 75 mg of levodopa plus entacapone; 1 mg of pergolide, pramipexole, lisuride, or cabergoline; 5 mg of ropinirole; and 10 mg of bromocriptine or apomorphine[6].

Statistical Analysis

The primary outcome measured in this study is the change in the global PSQI 6 months post-operatively compared to the pre-operative baseline using a paired t-test. Secondary outcomes include the subscore values for the PSQI, UPDRS part III scores, PDQ-39 scales and summary index, and LED. Subgroup analyses of the change in global PSQI, PSQI subscores, UPDRS part III, and LED from baseline to 3 months and from baseline to 6 months in subjects who underwent left versus right STN DBS were also performed. Additional subgroup analyses included evaluation of the change in global PSQI from baseline to 3 months and baseline to 6 months in subjects with a baseline global PSQI

greater than 5, which indicates a poor overall sleep quality based upon prior validation of the scale[22]. An overall assessment of changes from baseline was performed using a generalized linear model to evaluate repeated measures over time and pairwise contrasts for changes at 3 and 6 months from baseline. Statistical significance was considered to be achieved when the resulting p-value was <0.05 .

Results

Subjective sleep quality as measured by the global PSQI

Baseline global PSQI score for the 53 patients was 9.30 ± 0.56 (mean $\pm$ SEM) (Figure 2). At three and six months post-operatively, the mean global PSQI decreased to 8.78 ± 0.56 and 7.93 ± 0.56 , respectively. While the subjective sleep quality showed a trend toward improvement at 3 months ($p=0.334$), statistical significance was not seen until 6 months ($p=0.013$). Forty-two of the 53 (79.2%) patients had a baseline PSQI greater than 5, which indicates poor overall sleep quality based upon prior validation of the scale[22]. Subgroup analysis in those subjects with baseline PSQI greater than 5 showed more change over time, with a mean global PSQI of 10.67 ± 0.45 at baseline, 9.81 ± 0.58 at 3 months, and 8.67 ± 0.52 at 6 months post-operatively (Figure 2). Similar to the total group, this subgroup showed a trend toward improvement in sleep quality at 3 months ($p=0.229$), with statistically significant improvement at 6 months ($p=0.038$).

Subjective sleep quality based on side of surgery

Patients who underwent right STN DBS (those with worse left-sided motor symptoms) had more improvement in subjective sleep quality over 6 months ($p=0.012$) than patients who had left STN DBS ($p=0.60$) (Table 1). Additionally, those who had STN DBS on the right side had poorer baseline subjective sleep quality (10.32 ± 3.83) than patients who underwent left STN DBS (8.29 ± 3.68), $p=0.055$. In fact, 92% of subjects who underwent surgery on the right and 68% of subjects who underwent surgery on the left had a baseline global PSQI >5 .

Changes in PSQI subscores

Each PSQI subscore (sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleep medications, and daytime dysfunction) was evaluated, as reported in Table 2. There was no difference in the use of sleep medications before and after surgery and no change in subjective sleep efficiency. All other subscores showed a trend towards improvement, with subjective sleep quality and sleep disturbance having p values <0.01 . As mentioned previously, the use of sleep medications did not change over time. Classes of medications used by some of the subjects include benzodiazepines (alprazolam, clonazepam, diazepam, lorazepam), antipsychotics (quetiapine), anti-depressants (mirtazepine, trazodone) muscle relaxants (baclofen, cyclobenzaprine), anti-epileptic medications (gabapentin), and non-benzodiazepine hypnotics (zolpidem, eszopiclone). At baseline, 8 patients took two such medications, 21 patients took 1 medication, and 24 patients took none of these medications. At 3 months, 6 patients took 2 medications, 22 patients took 1 medication, and 25 patients took no medications. At 6 months, 1 patient took 3 medications, 8 patients took 2 medications, 18 patients took 1 medication, and 26 patients took no medications.

Subgroup analyses of PSQI subscores by side of surgery (Table 2) showed that subjects who underwent surgery on the right had improvement in sleep quality, sleep duration, and sleep disturbance, with trends toward improvement in daytime dysfunction and sleep efficiency. Subjects who underwent surgery on the left had a trend toward improvement only in sleep disturbance.

Motor improvement with unilateral STN DBS

As expected based on previous findings, patients who underwent unilateral STN DBS had a significant improvement in motor symptoms as measured by the UPDRS part III in the “practically defined off” medication state at 3 months post-operatively compared to pre-operative baseline (Figure 2). This improvement persisted at 6 months, although there was little change between the 3- and 6-month post-operative evaluations. This motor improvement allowed for decreased anti-Parkinsonian medications as measured by levodopa equivalent dose (LED). LED was 1198.4 ± 69.52 (mean $\pm$ SEM) at baseline, 936.64 ± 70.15 at 3 months ($p < 0.0001$), and 906.85 ± 69.52 ($p < 0.0001$) at 6 months post-operatively. Notably, there was no significant difference in the UPDRS part III or LED at any timepoint between subjects who underwent DBS on the right and those who underwent surgery on the left.

Quality of Life

Consistent with previous findings[8], quality of life as measured by the PDQ-39 improved after unilateral STN DBS. The PDQ-39 summary index (PDQ-39 SI) was 39.57 ± 2.14 (mean $\pm$ SEM) at baseline, 27.80 ± 2.01 ($p < 0.0001$) at 3 months, and 26.10 ± 1.70 ($p < 0.0001$) at 6 months post-operatively. Improvement was seen in the following PDQ-39 scales at 3 months post-operatively compared to baseline: mobility ($p < 0.0001$), ADLs ($p < 0.0001$), emotional well being ($p=0.024$), stigma ($p < 0.0001$), social support ($p=0.022$), and cognition ($p=0.020$). Improvement was also seen at 6 months compared to baseline in mobility ($p < 0.0001$), ADLs ($p < 0.0001$), stigma ($p < 0.0001$), cognition ($p=0.0005$), communication ($p=0.004$), and bodily discomfort ($p=0.007$). There was no significant change from 3 months to 6 months post-operatively in the PDQ-39 SI or any of the PDQ-39 scales.

Discussion

This study provides evidence that unilateral STN DBS significantly improves subjective sleep quality at 6 months post-operatively compared to the pre-operative baseline. Previous studies in patients with bilateral STN DBS have shown improvement in subjective sleep quality and in sleep architecture as measured by polysomnography[13–18], and one recent report described improvement in subjective sleep quality in a group of 12 patients with unilateral STN DBS[19]. Our study provides additional information about the effects of unilateral deep brain stimulation on this common non-motor symptom of PD.

The current study also shows worse pre-surgical subjective sleep quality in subjects who underwent STN DBS on the right (i.e. those who had most severe motor symptoms on the left) than in those with left STN DBS. Interestingly, previous studies have suggested that patients with the onset of Parkinson’s disease symptoms on the left side of the body have more nocturnal hallucinations and daytime sleepiness than patients with right-sided symptom onset, although there were no differences in PSG measures of sleep architecture[26]. Another study comparing non-motor symptoms in patients with right-versus left-sided symptom onset found no difference in sleep quality between the two groups[27]. Although these prior reports had differing outcomes, the current study does suggest that patients with predominance of motor symptoms on the left side of the body have more sleep dysfunction than patients with motor symptoms on the right.

In addition to the worse baseline sleep quality in patients who ultimately underwent right STN DBS, the improvement in sleep quality over time following STN DBS is more pronounced in patients who had surgery on the right. In fact, subjects with surgery on the right largely accounted for the improvement seen in the total group for global PSQI and the

PSQI subscores. It is unclear whether this difference in the two groups is related to a direct stimulation effect, through which DBS on the right affects sleep more than DBS on the left, or simply because the improvement is more easily detectable in patients with worse baseline sleep dysfunction. While the significance of these findings is not yet known, the results do provide an intriguing avenue for further study, and the unilateral surgical approach offers a unique opportunity to evaluate the effect of side of surgery on sleep outcomes. Importantly, motor symptoms measured by the UPDRS part III and the reduction in anti-Parkinsonian medications (LED) were not different between these two groups, showing that the observed differences in sleep quality by side of surgery do not simply reflect differences either in pre-operative motor disability or in motor improvement from unilateral DBS.

Evaluation of the PSQI subscores allowed for better determination of the changes that influence the improvement in global sleep quality. For the total group, improvement was most pronounced in the patient's interpretation of their sleep quality and sleep disturbance. Patients who underwent surgery on the right had improvement in these subscores as well as in sleep duration. There was no change in the use of sleep medications post-operatively despite the improvement in subjective sleep quality. The lack of significant change in administration of sleep medications may be related to the early emphasis on preferentially decreasing dopaminergic medications post-operatively or to the use of somnogenic medications for treatment of other co-morbidities of PD, such as depression, anxiety, psychosis, and pain. These medications may have been continued in order to treat these other indications even if they were no longer necessary for sleep.

There were some notable differences in our results compared to previous reports of subjective evaluation of sleep by PSQI in PD patients with bilateral STN DBS. In a study of 10 patients treated with bilateral STN DBS, Monaca and colleagues reported a change in global PSQI from 11.7 ± 2.4 pre-operatively to 5.3 ± 3.5 at 3 months[18]. Similarly, Iranzo reported a change in mean global PSQI from 14.8 ± 4.5 (mean $\pm$ SD) before bilateral STN DBS to 5.4 ± 4.6 at 6 months post-operatively in 11 PD patients[16]. Therefore, bilateral STN DBS is likely more effective in improving subjective sleep quality than unilateral STN DBS. However, a direct comparison is difficult because both studies on bilateral STN DBS had a smaller number of subjects and the studied subjects had considerably worse baseline sleep dysfunction pre-operatively. Additionally, whereas our series reports results from consecutive patients regardless of pre-operative sleep dysfunction, Monaca and colleagues only studied patients with baseline sleep complaints, which might introduce a ceiling effect or regression toward the mean in their estimates of sleep change. Further objective evaluation of sleep by polysomnography in patients who have undergone unilateral STN DBS followed by a staged contralateral procedure or in patients randomized to receive either unilateral or bilateral STN DBS might address the extent to which bilateral surgery is superior to unilateral STN DBS with regard to post-operative sleep improvement.

One other study has evaluated the effects of unilateral STN DBS on sleep in patients with Parkinson's disease. Chahine and colleagues evaluated subjective sleep quality using the Parkinson's Disease Sleep Scale (PDSS) in a combined group of 17 patients (12 subjects with unilateral STN DBS and 5 with bilateral stimulation)[19]. The authors reported significant improvement in the PDSS at 4 weeks post-operatively that persisted at 6 months. This study supports our findings that unilateral STN DBS improves sleep quality in Parkinson's disease.

There are some limitations to our study. First, we used a subjective measure of sleep quality in subjects who were not blinded to the intervention. Because participants are typically pleased with the motor outcomes from the DBS procedure, they may overstate positive subjective outcomes. Also, we did not study sleep quality in a control group of patients with

advanced PD who had not undergone STN DBS. Despite the use of within-patient comparisons, which reduces inter-subject variability, and the relatively large sample size in this series of patients, some proportion of the observed effects on sleep might represent a placebo effect. Therefore, future prospective studies with objective polysomnographic evaluation of sleep in subjects with DBS on versus off, and/or comparison to a control PD population without DBS would be beneficial. Another caveat is that we excluded patients who required STN DBS on the contralateral side prior to 6 months after the initial unilateral procedure, which potentially excluded subjects with more severe disease, more severe sleep dysfunction, or less motor benefit from the initial surgery. We believe this possibility is minimized as those patients accounted for only 10 of the 36 patients that were excluded from the analysis (11.2% of the total population of 89 patients). Finally, the PSQI was not specifically designed for evaluation of patients with Parkinson's disease and therefore does not address some features that may influence sleep in PD, such as dystonia and hallucinations. Regardless, the PSQI does measure many aspects of sleep that are often disrupted in PD patients, including sleep latency, sleep duration, sleep efficiency, nocturia, pain, dream content, and sleep disordered breathing. Indeed, the Sleep Scale Task Force division of the Movement Disorders Society Task Force on Rating Scales for PD has recommended use of either the PSQI or the PDSS to measure severity and presence of sleep problems in PD patients[28].

Sleep dysfunction in PD patients is likely multifactorial, with contributions from nocturnal immobility, depression, alterations in sleep architecture, and effects of anti-Parkinsonian medications. STN DBS allows for reduction in anti-Parkinsonian medications and improvement in nocturnal mobility and quality of life, and these changes could contribute to better sleep quality. In addition, it is possible that stimulation of the STN has effects on sleep architecture that are independent of improvement in motor symptoms or medication reduction. Our results support this conclusion because, although the UPDRS part III scores, the PDQ-39 SI, and the LED decreased significantly by the 3-month time point and then plateaued, the subjective sleep quality continued to improve over time to six months. This raises the possibility that STN stimulation might directly alter sleep physiology, which would not be unexpected considering the anatomical and physiological connections between the STN and structures in the brain that modulate sleep such as the pedunculopontine nucleus[29–31], the laterodorsal tegmental nucleus[30], and the dorsal raphe nucleus[31]. Additionally, studies in rats[32] and humans[33] have shown that the STN has different firing patterns depending on vigilance state, supporting the idea that alterations in STN firing through stimulation could directly influence sleep.

In summary, unilateral STN DBS improves subjective sleep quality in patients with moderate to severe idiopathic Parkinson's disease as measured by the Pittsburgh Sleep Quality Index. Additionally, subgroup analyses reveal that subjects who have worse motor symptoms on the left have poorer baseline sleep quality and more improvement in sleep following right STN DBS. Further objective evaluation of sleep architecture with polysomnography in patients with unilateral STN DBS is needed to better understand the underlying mechanism of sleep improvement. Non-motor symptoms in general, and sleep dysfunction in particular, are closely tied to quality of life in patients with PD[1]. Understanding the impact of this intervention on sleep and other non-motor symptoms could influence future treatment strategies.

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Figure 1.
Flow chart for study

Figure 2.

A: Primary Outcome Measure: Change in Global PSQI over time

B: Subgroup Analysis: Change in Global PSQI over time in subjects with baseline PSQI > 5

C: Secondary Outcome Measure: Change in UPDRS over time

Values are mean ± SEM

UPDRS: Unified Parkinson's Disease Rating Scale

Table 1

Subgroup analysis: Change in global PSQI in subjects with left or right STN DBS

	Pre-operative baseline	3 month followup	p value	6 month followup	p value
Mean Global PSQI Left STN (n=28)	8.29 ± 3.68 ^a	8.14 ± 3.98 ^a	0.82	7.89 ± 3.87 ^a	0.60
Mean Global PSQI Right STN (n=25)	10.32 ± 3.83 ^a	9.36 ± 4.41 ^a	0.29	7.84 ± 3.54 ^a	0.012

^a mean ± standard deviation

Table 2

Secondary outcome measure: PSQI subscores

	Pre-operative baseline	3 month followup	p value	6 month followup	p value
Sleep Quality					
Total	1.47 ± 0.10 ^a	1.26 ± 0.10 ^a	0.054	1.15 ± 0.10 ^a	0.003 *
Left	1.21 ± 0.12 ^a	1.28 ± 0.14 ^a	0.626	1.25 ± 0.14 ^a	0.813
Right	1.76 ± 0.19 ^a	1.24 ± 0.16 ^a	0.001 *	1.04 ± 0.12 ^a	0.0003 *
Sleep Duration					
Total	1.56 ± 0.17 ^a	1.51 ± 0.17 ^a	0.738	1.32 ± 0.17 ^a	0.149
Left	1.36 ± 0.19 ^a	1.36 ± 0.22 ^a	1.000	1.54 ± 0.22 ^a	0.326
Right	1.72 ± 0.26 ^a	1.60 ± 0.24 ^a	0.718	1.00 ± 0.22 ^a	0.008 *
Sleep Latency					
Total	0.68 ± 0.07 ^a	0.47 ± 0.07 ^a	0.011 *	0.55 ± 0.07 ^a	0.100
Left	0.61 ± 0.09 ^a	0.36 ± 0.09 ^a	0.032 *	0.46 ± 0.10 ^a	0.212
Right	0.76 ± 0.09 ^a	0.60 ± 0.10 ^a	0.212	0.64 ± 0.10 ^a	0.273
Sleep Efficiency					
Total	1.23 ± 0.18 ^a	1.33 ± 0.18 ^a	0.652	1.20 ± 0.18 ^a	0.857
Left	0.93 ± 0.22 ^a	1.00 ± 0.23 ^a	0.769	1.18 ± 0.25 ^a	0.388
Right	1.52 ± 0.27 ^a	1.64 ± 0.26 ^a	0.705	1.16 ± 0.24 ^a	0.321
Sleep Disturbance					
Total	1.62 ± 0.08 ^a	1.47 ± 0.08 ^a	0.132	1.30 ± 0.08 ^a	0.002 *
Left	1.57 ± 0.11 ^a	1.46 ± 0.10 ^a	0.415	1.32 ± 0.10 ^a	0.070
Right	1.68 ± 0.13 ^a	1.48 ± 0.15 ^a	0.233	1.28 ± 0.12 ^a	0.030 *
Daytime Dysfunction					
Total	1.21 ± 0.13 ^a	1.06 ± 0.13 ^a	0.306	0.93 ± 0.13 ^a	0.056
Left	1.21 ± 0.18 ^a	1.14 ± 0.18 ^a	0.691	1.07 ± 0.21 ^a	0.526

	Pre-operative baseline	3 month followup	p value	6 month followup	p value
Right	1.32 ± 0.95 ^a	1.08 ± 0.19 ^a	0.207	0.88 ± 0.17 ^a	0.102
Sleep Medication					
Total	1.47 ± 0.20^a	1.62 ± 0.20^a	0.373	1.43 ± 0.20^a	0.823
Left	1.39 ± 0.28 ^a	1.54 ± 0.27 ^a	0.424	1.07 ± 0.26 ^a	0.204
Right	1.56 ± 0.26 ^a	1.72 ± 0.30 ^a	0.566	1.84 ± 0.29 ^a	0.306

^a mean ± SEM;

* p < 0.05