Hallucinations, Dreaming, and Frequent Dozing in Parkinson Disease: Impact of Right-hemisphere Neural Networks

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Objective: To relate sleep disturbances in Parkinson disease (PD) to hemispheric asymmetry of initial presentation.

Background: Sleep disturbances are common in PD arising from the neurodegenerative process underlying the disease, which is usually lateralized at onset. Patients with left-side Parkinson disease onset (LPD: right hemisphere dysfunction) exhibit reduced vigilance relative to those with right-side Parkinson disease onset (RPD: left hemisphere dysfunction), leading us to hypothesize that sleep-related disturbances, particularly excessive daytime sleepiness, would be more severe for LPD than for RPD.

Methods: Thirty-one nondemented participants with PD (17 RPD and 14 LPD) and 17 age-matched control (CO) participants with chronic health conditions were administered the Parkinson Disease Sleep Scale and polysomnography was performed on a subset of the PD participants.

Results: Both PD subgroups exhibited more nighttime motor symptoms than the CO group, but only LPD endorsed more nocturnal hallucinations and daytime dozing. Controlling for mood additionally revealed more vivid dreaming in LPD than RPD. There were no significant differences between LPD and RPD on measures of sleep architecture.

Conclusions: Increased dreaming, hallucinations, and daytime somnolence in LPD may be related to changes in right-hemisphere neural networks implicated in the generation and control of visual images, arousal, and vigilance. Our results underscore the need to consider side of onset in regard to sleep disturbances in PD.

Key Words: Parkinson disease, hemiparkinsonism, sleep disturbances, hypersomnia

Parkinson disease (PD) is a neurodegenerative disorder that is characterized by the disruption of dopaminergic projections from the substantia nigra to the basal ganglia. Besides being a motor disorder, it leads to impairments in cognition, perception, and sleep, and also to neuropsychiatric symptoms.

Sleep problems are estimated to occur in over 75% of patients with PD over the course of the disease. The most common are sleep fragmentation, sleep-related breathing disorders, restless legs-periodic leg movements, rapid eye movement (REM) behavior sleep disorder, and sleep-related psychosis (ie, nocturnal hallucinations). Patients also experience disturbances of arousal, namely sleep attacks and excessive daytime sleepiness.

Motor signs of PD typically begin on one side of the body. Side of onset is a significant, but often overlooked, clinical and neuropathologic factor in the study of PD. Those patients whose symptoms begin on the left side of the body [left-side Parkinson disease (LPD)] have greater right hemisphere pathology and those with symptoms starting on the right [right-side Parkinson disease (RPD)] have greater left hemisphere pathology.

Motor-symptom asymmetry in PD predicts visuospatial and vigilance deficits and fatigue in LPD and poorer verbal memory performance in RPD. The side of initial onset tends to remain more affected as the disease progresses and the basal ganglia and substantia nigra show considerable neuropathologic asymmetry.

In the present study, we aimed to relate sleep disturbances in PD to the hemispheric side of onset. As some sleep-related disturbances, such as excessive daytime sleepiness, may precede the manifestation of motor symptoms by several years, identifying and treating these sleep problems early may enhance functioning and protect quality of life for patients ultimately diagnosed with PD.

The link between left-onset symptoms and reductions in vigilance led us to hypothesize that sleep disturbances, particularly excessive daytime sleepiness,
would be more severe in LPD than RPD. Group differences were examined on a variety of sleep disturbances using the Parkinson Disease Sleep Scale (PDSS) and sleep architecture using overnight polysomnography (PSG).

**METHODS**

**Participants**

Thirty-one patients with PD (30 men and 1 woman) were recruited from the outpatient Movement Disorders Clinic at the Veterans Administration Boston Healthcare System. Seventeen age-matched control subjects (CO) (10 men and 7 women) were recruited from the Veterans Administration community. The study was approved by the Boston University Medical Center and Veterans Administration Institutional Review Boards and all participants provided informed consent. Individuals meeting Diagnostic and Statistical Manual of Mental Disorder, 4th edition or Emre and colleagues' criteria for dementia or those who scored 23 or below on the Mini Mental State Examination were excluded, as were those with a history of substance abuse, head injury, or posttraumatic stress disorder. None of the patients met criteria for dementia with Lewy bodies as per McKeith and colleagues. All CO participants presented with a chronic debilitating condition including chronic back pain, diabetes, or cancer, but not any neurologic disorders.

PD medication information was obtained by the neurologist (R.D.) and levodopa equivalent dosages were calculated on the basis of previous reports with 100 mg levodopa = 83 mg levodopa with a catechol-O-methyl transferase inhibitor = 1 mg pramipexole = 1 mg pergolide. All PD patients were taking levodopa and 22 were on dopamine agonists (10 RPD and 12 LPD). In addition, 2 RPD and 1 LPD were taking selegiline and 1 RPD and 2 LPD were taking amantadine. No participant was taking anticholinergic medication. Side of motor symptom onset was obtained by patient report and motor examination by the neurologist. Motor symptom severity was quantified using the Unified Parkinson Disease Rating Scale (UPDRS) and Hoehn and Yahr stage. Asymmetry was calculated as the sum of scores of right and left-sided UPDRS items measuring tremor, rigidity, finger taps, alternating hand movements, leg agility, and arm swing.

**Measures**

**PD and CO Groups**

Mood was assessed using the Depression, Anxiety, and Stress Scale (DASS). The measure consists of 21 questions in 3 subscales of depression, anxiety, and stress, and a total mood score, with higher scores indicating greater impairment.

Subjective sleep complaints were assessed using the PDSS, a simple screening measure of sleep disturbances. To date, the PDSS is the only formal, validated instrument designed to quantify various aspects of sleep problems in PD. It has been used in identifying sleep disturbances such as sleep maintenance insomnia and excessive daytime sleepiness. The scale consists of 15 common symptoms. A score of 0 indicates worse symptoms/poorer quality of sleep and 10 indicates no symptoms/better quality of sleep. In the current study, the 15 items were examined as 9 factors comprising composite scores of the individual items, as described elsewhere. The factors were overall quality of sleep, sleep onset and maintenance insomnia, nocturnal restless sleep, nocturnal hallucinations, distressing/vivid dreams, nocturia, nocturnal motor symptoms (including sensory complaints, early morning dystonia, and cramps during the night), sleep refreshment, and daytime dozing.

**PD Group**

Standard overnight PSG was performed on 11 RPD and 7 LPD, who agreed to participate, at the General Clinical Research Center of the Boston University Medical Center. The electroencephalogram (EEG) was recorded from the C3 and C4 electrodes and was referenced to an average of A1 and A2. The PSG monitored body functions including brain electrical activity (EEG), eye movements (electrooculogram), muscle activity (electromyogram), and respiratory effort. Number of awakenings, sleep latency and total sleep time (minutes), stages REM, 1, 2, 3, 4, sleep efficiency, and wake-time after sleep onset (minutes) were calculated with Compumedics ProFusion PSG2 Software.

**Statistical Analyses**

Analyses of variance were performed to examine differences between the RPD, LPD, and CO groups followed by post-hoc analyses when indicated. For variables relevant only to the PD groups (eg, motor symptom asymmetry, medication dosages, and polysomnographic measures), Bonferroni-corrected independent-sample tests were performed. These analyses were followed by analyses of covariance controlling for total mood score (DASS-total). Multiple regression analyses were conducted using PDSS-derived sleep factors as criterion variables and group and DASS-total as predictor variables. Finally, all analyses were repeated excluding women (1 LPD; 7 CO) because of their low representation in the sample.

**RESULTS**

Clinical and demographic characteristics of the groups are presented in Table 1. There were no significant differences between groups in age, education, or Mini Mental State Examination. RPD presented with significantly higher DASS-stress, DASS-anxiety, and DASS-depression scores than the CO group, but no differences were found between the LPD and CO or between the 2 PD groups. There were no significant differences between RPD and LPD in disease severity as indexed by Hoehn and Yahr stage (\(\chi^2 = 4.32, P = 0.12\)) or duration [\(t(28) = 0.75, P = 0.46\)]. As expected, on the UPDRS, RPD presented with greater motor symptom severity on the right side and LPD on the left side. RPD presented with greater total UPDRS score than LPD [\(t(13) = -2.5, P = 0.034\)].
The PD groups did not differ in levodopa dosage equivalents of dopaminergic medication [\(t(27) = 0.22, P = 0.83\)].

The results of the sleep questionnaire are reported in Table 2. There were overall group differences in the PDSS-total score \([F(2,45) = 5.03, P = 0.01]\), nocturnal hallucinations \([F(2,45) = 5.87, P = 0.005]\), nocturia \([F(2,45) = 3.2, P = 0.048]\), nocturnal motor symptoms \([F(2,45) = 5.91, P = 0.005]\), and daytime dozing \([F(2,45) = 9.19, P < 0.0001]\]. RPD and LPD both endorsed more symptoms than CO on the PDSS-total \((P = 0.04\) and \(P = 0.02\), respectively). LPD reported significantly greater frequency of nocturnal hallucinations than CO \((P = 0.004)\), whereas RPD did not differ from CO \((P = 0.13)\). There was a trend toward LPD endorsing more symptoms of nocturia than CO \((P = 0.06)\). No differences were apparent between the PD groups \((P = 1.0)\) or between RPD and CO \((P = 0.21)\). Both PD groups reported significantly more frequent nocturnal motor symptoms than CO \((RPD P = 0.01; LPD P = 0.02)\), but did not differ from each other \((P = 1.0)\). Relative to CO, LPD showed more frequent daytime dozing \((P < 0.0001)\), with RPD showing a similar trend \((P = 0.06)\).

Because RPD presented with higher stress, anxiety, and depression scores than LPD or CO, and all 3 mood scores were negatively associated with items on the PDSS, analyses were repeated with overall mood score (DASS-total) as a covariate. The 3 groups were significantly different on nocturnal hallucinations \([F(1,44) = 4.86, P = 0.01]\) and daytime dozing \([F(1,44) = 7.01, P = 0.002]\) with a trend for frequency of vivid dreams \([F(1,44) = 2.89, P = 0.07]\) (Fig. 1). The groups no longer differed on the PDSS-total \([F(2,44) = 2.04, P = 0.14]\) and nocturia \([F(2,44) = 2.12, P = 0.13]\). Post-hoc analyses

### TABLE 1. Demographic and Clinical Characteristics of Control Subjects (CO), Patients With Right-side Onset PD (RPD), and Patients With Left-side Onset PD (LPD)

<table>
<thead>
<tr>
<th></th>
<th>CO (n = 17)</th>
<th>RPD (n = 17)</th>
<th>LPD (n = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (in y)</td>
<td>65.6 (7.5)</td>
<td>71.5 (12.1)</td>
<td>67.6 (10.6)</td>
</tr>
<tr>
<td>Education (in y)</td>
<td>15.2 (2.0)</td>
<td>13.3 (2.7)</td>
<td>13.8 (2.7)</td>
</tr>
<tr>
<td>MMSE</td>
<td>27.9 (1.6)</td>
<td>26.4 (2.2)</td>
<td>26.5 (2.5)</td>
</tr>
<tr>
<td>DASS total mood score</td>
<td>5.76 (4.5)</td>
<td>17.1 (11.4)*</td>
<td>12.4 (9.2)</td>
</tr>
<tr>
<td>Hoehn and Yahr stage‡</td>
<td>n/a</td>
<td>2.00 (2.0-4.0)</td>
<td>3.00 (1.0-3.0)</td>
</tr>
<tr>
<td>UPDRS right total</td>
<td>n/a</td>
<td>7.35 (2.4)</td>
<td>3.43 (3.1)†</td>
</tr>
<tr>
<td>UPDRS left total</td>
<td>n/a</td>
<td>3.18 (1.6)</td>
<td>5.36 (3.0)†</td>
</tr>
<tr>
<td>UPDRS total</td>
<td>n/a</td>
<td>19.7 (5.0)</td>
<td>13.3 (4.5)†</td>
</tr>
<tr>
<td>Disease duration</td>
<td>n/a</td>
<td>6.76 (4.2)</td>
<td>8.15 (5.9)</td>
</tr>
<tr>
<td>Levodopa equivalent dose (mg/d)</td>
<td>n/a</td>
<td>477.4 (219.4)</td>
<td>499.7 (328.3)</td>
</tr>
</tbody>
</table>

Means (SD) are reported.

*Significant difference from CO at \(P < 0.01\) level.

†Significant difference from RPD at \(P < 0.01\) level.

‡Median (range) is reported.

CO indicates control; DASS, Depression, Anxiety, and Stress Scale; LPD, left-side onset Parkinson disease; MMSE, Mini-Mental Status Examination; n/a, not applicable; RPD, right-side onset Parkinson disease; UPDRS, Unified Parkinson Disease Rating Scale.

### TABLE 2. A Comparison of Sleep Factors in Patients With Right and Left Side of Onset PD as Assessed With the Parkinson Disease Sleep Scale (PDSS)

<table>
<thead>
<tr>
<th></th>
<th>CO (n = 17)</th>
<th>RPD (n = 17)</th>
<th>LPD (n = 14)</th>
<th>RPD (PSG) (n = 11)</th>
<th>LPD (PSG) (n = 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
<td>5.71 (2.0)</td>
<td>5.35 (3.1)</td>
<td>5.21 (2.7)</td>
<td>6.00 (3.00)</td>
<td>5.00 (2.8)</td>
</tr>
<tr>
<td>Insomnia</td>
<td>12.2 (4.5)</td>
<td>12.4 (4.9)</td>
<td>12.6 (4.6)</td>
<td>13.3 (4.7)</td>
<td>13.2 (4.9)</td>
</tr>
<tr>
<td>Restlessness</td>
<td>16.4 (4.0)</td>
<td>13.6 (5.5)</td>
<td>15.5 (3.6)</td>
<td>15.2 (3.8)</td>
<td>16.5 (3.5)</td>
</tr>
<tr>
<td>Dreams</td>
<td>8.29 (1.9)</td>
<td>8.35 (1.3)</td>
<td>6.93 (2.7)‡</td>
<td>8.33 (1.4)</td>
<td>7.30 (3.0)</td>
</tr>
<tr>
<td>Night hallucinations</td>
<td>9.94 (0.24)</td>
<td>9.18 (1.3)</td>
<td>8.00 (2.5)‡‡</td>
<td>9.11 (1.7)</td>
<td>7.70 (2.83)</td>
</tr>
<tr>
<td>Nocturia</td>
<td>14.8 (3.7)</td>
<td>12.2 (3.7)</td>
<td>11.2 (5.1)</td>
<td>11.9 (4.5)</td>
<td>10.8 (5.9)</td>
</tr>
<tr>
<td>Motor symptoms</td>
<td>36.0 (5.0)</td>
<td>27.8 (8.1)*</td>
<td>27.8 (10.3)†</td>
<td>27.3 (8.5)</td>
<td>26.9 (12.1)</td>
</tr>
<tr>
<td>Refreshment</td>
<td>7.12 (2.2)</td>
<td>5.29 (3.1)</td>
<td>5.79 (2.7)†</td>
<td>6.22 (4.49)</td>
<td>6.10 (2.73)</td>
</tr>
<tr>
<td>Daytime dozing</td>
<td>7.82 (2.1)</td>
<td>5.59 (3.0)</td>
<td>3.71 (2.9)‡‡</td>
<td>5.67 (2.78)</td>
<td>3.10 (3.0)</td>
</tr>
<tr>
<td>PDSS total</td>
<td>118.2 (16.6)</td>
<td>99.6 (24.1)*</td>
<td>95.8 (21.6)†</td>
<td>102.9 (24.3)</td>
<td>96.6 (24.4)</td>
</tr>
</tbody>
</table>

Data are reported from the entire sample and only patients who completed overnight PSG. A higher score indicates less frequent symptoms, whereas a lower score indicates more frequent symptoms. Means (SD) are reported.

*Significant difference from CO at \(P < 0.05\) level.

†Significant difference from CO when controlling for DASS-total at \(P < 0.05\) level.

‡Significant difference from RPD when controlling for DASS-total at \(P < 0.05\) level.

CO indicates control; DASS, Depression, Anxiety, and Stress Scale; LPD, left-side onset Parkinson disease; PD, Parkinson disease; PDSS, Parkinson Disease Sleep Scale; PSG, polysomnography; RPD, right-side onset Parkinson disease.
revealed significant differences between LPD and CO \((P = 0.007)\), but not between RPD and CO \((P = 0.65)\) on nocturnal hallucinations. LPD reported more hallucinations than RPD \((P = 0.02)\). LPD reported significantly more distressing dreams than RPD \((P = 0.02)\) with no differences between either PD group and CO \((P = 0.32; \text{LPD} P = 0.20)\). Similarly, for daytime dozing, no differences were found between RPD and CO \((P = 0.16)\), but LPD reported more frequent daytime dozing than CO \((P = 0.001)\) and RPD \((P = 0.01)\).

To investigate whether the higher frequency of vivid dreaming, hallucinations, and daytime dozing in LPD was associated with disease severity, Spearman rank-order correlations were performed for LPD and RPD separately. No significant correlations were found between Hoehn and Yahr stage and any of these symptoms for either group \((P > 0.1\) in each case). For the UPDRS-total score, Pearson correlation was significant with vivid dreaming for LPD \((P = 0.02)\), but not RPD \((P = 0.5)\). Hallucinations and daytime dozing were not correlated with UPDRS-total for either PD group \((P > 0.2\) in each case). No association was found between the UPDRS asymmetry score for right and left side and hallucinations, vivid dreams, or daytime dozing \((P > 0.1)\).

All of the above analyses were repeated excluding women because of their low representation in the sample. All significant differences between the 3 groups remained for all of the above analyses. Further, frequency of vivid dreams became significantly different \([F(2,37) = 3.97, P = 0.03]\) across groups, with LPD reporting more vivid dreams than CO \((P = 0.02)\), but no differences between CO and RPD \((P = 0.49)\) nor between the PD groups \((P = 0.21)\). Polysomnographic findings are reported in Table 3. Two RPD presented with a respiratory distress index above 30, indicating the presence of severe obstructive sleep apnea. Two additional RPD presented with a respiratory distress index of 12.2 and 15.8, indicating mild obstructive sleep apnea. No other patient showed respiratory distress indicative of sleep apnea. Analysis of sleep EEG findings demonstrated a virtual absence of slow-wave sleep (stages III and IV), normal amounts of REM, and “light” stage II sleep. Bonferroni-corrected

<table>
<thead>
<tr>
<th>TABLE 3. A Comparison of Sleep Architecture in Patients With RPD and LPD</th>
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<td></td>
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<td>------------------</td>
</tr>
<tr>
<td>RDI</td>
</tr>
<tr>
<td>Number awakenings</td>
</tr>
<tr>
<td>WASO (in min)</td>
</tr>
<tr>
<td>Sleep latency (in min)</td>
</tr>
<tr>
<td>Total sleep time (in min)</td>
</tr>
<tr>
<td>Sleep efficiency</td>
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<tr>
<td>Stage REM</td>
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<tr>
<td>Stage 1</td>
</tr>
<tr>
<td>Stage 2</td>
</tr>
<tr>
<td>Stage 3</td>
</tr>
<tr>
<td>Stage 4</td>
</tr>
</tbody>
</table>

Means (SD) are reported.

LPD indicates left-side onset Parkinson disease; RDI indicates Respiratory Distress Index; REM, rapid eye movement; RPD, right-side onset Parkinson disease; WASO, wake onset sleep latency.
involved in the control of sleep/wake cycles are linked to pedunculopontine (PPTG) and other brainstem regions directly.

rostral transmission of PGO waves from the brainstem pedunculopontine tegmentum. The role of the basal network that connects the brainstem to the cortex and occipital (PGO) waves.

Dreaming and visual hallucinations are related to REM sleep. The basal ganglia neural networks are part of the thalamocortical circuit projecting to cortical areas involved in higher-order visual processing. Imaging studies of patients with dementia with Lewy bodies and of patients with PD have demonstrated selective activation of right-hemisphere brain regions (ie, right parietal and temporal areas) in patients with visual hallucinations. In normal adults, despite the general deactivation of the parietal and frontal cortices during REM sleep dreaming, there is selective activation of the right parietal operculum. In PD, abnormal functioning of the basal ganglia-thalamocortical circuitry may increase the thalamic input to right temporoparietal areas and lead to abnormal PGO activity. Consequently, these alterations in right-hemisphere cortical activation may result in disturbed visual processing and more frequent dreaming in patients with PD.

Hallucinations and excessive daytime sleepiness in PD are considered by some to be a side effect of dopaminergic medication rather than a part of the disease process. Several studies have demonstrated, however, that hallucinations are not related to dose or duration of medication and high-dose levodopa infusions do not induce hallucinations in PD. With respect to daytime sleepiness, although there is compelling evidence for dopaminergic medication as a direct cause of drowsiness, it is clear that other disease-related factors may also contribute to the development of daytime somnolence. In our sample, daytime sleepiness and hallucinations in LPD alone could not be attributed solely to the use of dopaminergic medications, as there were no LPD-RPD differences in dose of either levodopa or dopamine agonists.

An important limitation of our study is the low representation of women, especially in the PD groups. Sex differences have been reported for nonmotor symptoms of PD, with women presenting more often with depression and men presenting more often with behavioral

DISCUSSION

To our knowledge, this is the first report that shows that significant sleep disturbances in PD are related to the side of motor symptom onset. We found that both RPD and LPD reported more frequent sleep disturbances than the CO group. LPD experienced more nocturnal hallucinations, disturbing dreams, and excessive daytime sleepiness than RPD. The differences between LPD and RPD were not accounted for by differences in age, disease severity, medication type, or dosage, as the groups did not differ on any of these factors, nor in mood, as all analyses were performed after adjusting for differences in mood scores. The differences between LPD and RPD in self-reported sleep disturbances were not accounted for by differences in EEG-measured sleep architecture as no such differences emerged when overnight PSG was performed. In addition, the greater frequency of reported daytime dozing in LPD than RPD cannot be accounted for by obstructive sleep apnea, as polysomnographic findings revealed the presence of sleep apnea in 4 patients with RPD and none with LPD.

Though the physiologic substrates of hallucinations and dreaming are yet to be completely understood, there is some evidence that in PD, vivid dreaming and sleep disruptions may serve as precursors to hallucinations. Dreaming and visual hallucinations are related to REM sleep and may be mediated by the ponto-geniculo-occipital (PGO) waves that have been detected in animals during REM sleep and implicated in dream-related internal stimulus generation and visual perceptions. Because the PGO generator (nucleus pedunculopontinus) and other brainstem regions directly involved in the control of sleep/wake cycles are linked to the neurodegenerative process of PD, it has been suggested that abnormal PGO activity could be responsible for generation of vivid dreaming and hallucinations during wakefulness in these patients.

The basal ganglia may play an important role in regulating sleep/wake activity. Neuroimaging studies in healthy adults have demonstrated particularly robust increases in activation of the basal ganglia during transition from wakefulness to slow wave and to REM sleep. The basal ganglia are involved in the mediating network that connects the brainstem to the cortex and this network contains multiple back-projections to the pedunculopontine tegmentum. The role of the basal ganglia in sleep/wake activity may, therefore, be the regulation of ascending thalamocortical activation and rostral transmission of PGO waves from the brainstem through the thalamus to the forebrain.

Alterations in right-hemispheric cortical activation via asymmetrical basal ganglia functioning may explain disturbed visual processing and more frequent dreaming in patients with PD. The basal ganglia neural networks are part of the thalamocortical circuit projecting to cortical areas involved in higher-order visual processing. Imaging studies of patients with dementia with Lewy bodies and of patients with PD have demonstrated selective activation of right-hemisphere brain regions (ie, right parietal and temporal areas) in patients with visual hallucinations. In normal adults, despite the general deactivation of the parietal and frontal cortices during REM sleep dreaming, there is selective activation of the right parietal operculum. In PD, abnormal functioning of the basal ganglia-thalamocortical circuitry may increase the thalamic input to right temporoparietal areas and lead to abnormal PGO activity. Consequently, these alterations in right-hemisphere cortical activation may result in disturbed visual processing and more frequent dreaming in patients with PD.

Right-hemisphere dysfunction may also account for more frequent daytime dozing in PD. Excessive daytime sleepiness is a common nonmotor symptom that occurs in approximately 30% of nondemented patients with PD. Right-hemisphere neural networks have been implicated in arousal and vigilance levels in healthy adults, and these right-hemisphere vigilance functions are particularly sensitive to sleep deprivation. There is also evidence for a functional deterioration of the fronto-temporoparietal network in the right hemisphere of patients with narcolepsy, a disorder characterized by the loss of hypocretin-secreting neurons. Although no studies have examined laterality in the loss of hypocretin neurons of the hypothalamus, in patients with PD there is significant loss of these neurons, increasing with disease severity and progression. Impairment in right-hemisphere functions consequently could account for more frequently reported excessive daytime sleepiness in PD.

Hallucinations and excessive daytime sleepiness in PD are considered by some to be a side effect of dopaminergic medication rather than a part of the disease process. Several studies have demonstrated, however, that hallucinations are not related to dose or duration of medication and high-dose levodopa infusions do not induce hallucinations in PD. With respect to daytime sleepiness, though, there is compelling evidence for dopaminergic medication as a direct cause of drowsiness; it is clear that other disease-related factors may also contribute to the development of daytime somnolence. In our sample, daytime sleepiness and hallucinations in LPD alone could not be attributed solely to the use of dopaminergic medications, as there were no LPD-RPD differences in dose of either levodopa or dopamine agonists.

An important limitation of our study is the low representation of women, especially in the PD groups. Sex differences have been reported for nonmotor symptoms of PD, with women presenting more often with depression and men presenting more often with behavioral...
disturbances. Likewise, sex differences seem to exist for sleep disorders, with women reporting a higher prevalence of insomnia and restless legs syndrome, whereas REM behavior sleep disorder, characterized by loss of normal muscle tone and acting-out of dreams, is more common in men. Underlying the sex differences in both sleep and nonmotor symptoms of PD may be distinct pathophysiological mechanisms, which underscores the importance of including both men and women in future studies of the etiology and symptomatology of PD.

In our sample, RPD presented with higher scores on a measure of stress, anxiety, and depression than did the LPD and CO group. In all 3 groups, these symptoms were related to the subjective sleep disturbances, with those endorsing more mood symptoms also reporting higher frequency of sleep-related problems. There is evidence that mood symptoms impact sleep complaints in both younger and older adults, with those expressing a greater degree of sleep problems also reporting more mood symptoms such as depression and anxiety. In the current study, adjusting for mood symptoms highlighted significant differences between patients with LPD and RPD on the dreams, hallucinations, and daytime dozing items of the sleep questionnaire, thereby emphasizing the group differences in sleep disturbances that are intrinsic to the disease rather than secondary to other disease-related symptoms such as depression and anxiety.

The current study did not find any hemispheric differences in sleep architecture between LPD and RPD. PSG limited to 1 night, however, may have missed important sleep disorders that are common in PD, namely REM behavior sleep disorder and restless legs syndrome. In light of the current finding of side-of-onset differences in sleep-related disturbances, it is important for future studies examining a wider range of objective sleep measures in PD to consider side of symptom onset.

In summary, we found an effect of side of motor symptom onset on sleep disturbances in PD. In particular, there were differences in the frequency of reported distressing/vivid dreams, hallucinations, and daytime dozing. Research is needed to understand how the side of symptom onset is related to specific sleep disorders, such as REM behavior sleep disorder and restless legs syndrome, which are common in PD and are likely related to the neuropathologic process of the disease. Elucidating the etiology of sleep disturbances in PD is important as identification and early treatment of these disturbances may substantially enhance the quality of life in patients with this disease.

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