Non-motor Parkinson disease: new concepts and personalised management

Nataliya Titova1, K Ray Chaudhuri2

Non-motor symptoms (NMS) of Parkinson disease (PD) were recognised by James Parkinson, a London-based physician in his 1817 essay on the condition he called “the shaking palsy” or “paralysis agitans”. He described a complex condition with tremor, gait abnormalities and stooped posture intermixed with NMS such as sleep dysfunction, delirium, dementia and dysautonomia. However, NMS remained under-recognised and poorly researched until the introduction of comprehensive tools such as the NMS Questionnaire (https://www.pdnmg.com/imagemlib/pdf/nms-quest.pdf) and NMS Scale (https://www.pdnmg.com/imagemlib/pdf/nms-scale08.pdf) in the early 2000s, and the recognition of PD as a condition of many origins, termed the Parkinson complex in 2006 and subsequently classified as a syndrome in 2017.2,4 The assessment tools have helped to assess NMS holistically and to outline the effect of their burden on quality of life in PD.5,6 NMS assessment in the outpatient clinic is now considered to be good clinical practice in many countries. Recent attempts to redefine PD have viewed it as a complex combination of motor and non-motor disorders, with a natural history that includes a prodromal phase dominated by a range of NMS. NMS-driven biomarkers may define prodromal PD and enable the identification of patients at risk of developing motor PD and the development of new neuroprotective therapies. Validated burden grading of NMS is also being increasingly used as an outcome measure in clinical trials.7,8 Finally, the complex multi-neurotransmitter dysfunction of PD may underpin recently described non-motor subtypes.4 Recognition of such subtypes may lead to the emergence of personalised and precision medicine in the management of PD.5

This narrative review is based on a PubMed review of original and review articles from 1999 to 2017 as well as specialist society publications and relevant guidelines to formulate an evidence-based overview of the topics, as applied to clinical practice.

Non-motor symptoms in Parkinson disease

PD is the second most common neurodegenerative disorder in the world, with a global prevalence of about 200 per 100 000 individuals.10 About one person is diagnosed every hour, one in 50 people over 80 years of age are likely to be diagnosed with PD, and about 10% of those diagnosed are below 40 years of age.10 The number of people with PD is rising worldwide because of increasing life expectancy, and the number of diagno-ses is expected to double by 2040. PD is now recognised to be as much a non-motor disorder as a motor disorder, with a complex range of NMS present in the prodromal stage as well as in the various motor disorder stages until the final palliative stage11,12 (Box 1).

Prodromal non-motor Parkinson disease

The prodromal period of PD is now well established (Box 1). This phase is recognised by a range of NMS which include hyposmia, rapid eye movement sleep behaviour disorder (RBD) and other NMS shown in Box 2. Several cohort studies are in progress to establish how best to determine this prodromal period, which may last up to 10 years. The International Parkinson and Movement Disorder Society (MDS) has also attempted to define the prodromal period based on several NMS (eg, RBD, hyposmia, constipation, excessive daytime constipation), as well as some motor features (eg, abnormal quantitative motor testing) and other factors (eg, age, occupational exposure to solvents or pesticides, smoking, family history), and then calculate a likelihood ratio for later development of manifest PD.33 Identification of the prodromal period is of crucial importance to enable early initiation of neuroprotective therapies at a stage when molecular degeneration begins rather than waiting until motor symptoms commence. Mutations in glucocerebrosidase or leucine-rich protein kinase genes have been implicated to mark an even earlier (pre-prodromal) stage of PD when there are no symptoms but susceptibility to PD exists (Box 1). Imaging using positron emission tomography, transcranial ultrasound and cardiac metaiodobenzylguanidine (MIBG) scans have all been suggested as possible biomarkers in the prodromal period of PD. More recently, the role of skin biopsy as an RBD biomarker has been proposed, and cardiac MIBG scanning is now included as a supportive criterion for the clinical diagnosis of PD.15,13,14

Reference

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Box 2

<table>
<thead>
<tr>
<th>Non-motor symptoms</th>
<th>Description</th>
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<tbody>
<tr>
<td>Hyposmia</td>
<td>Loss of smell</td>
</tr>
<tr>
<td>RBD</td>
<td>Rapid eye movement sleep behaviour disorder</td>
</tr>
<tr>
<td>Constipation</td>
<td>Excessive daytime constipation</td>
</tr>
<tr>
<td>Delirium</td>
<td>Temporary confusion</td>
</tr>
<tr>
<td>Dysautonomia</td>
<td>Autonomic dysfunction</td>
</tr>
</tbody>
</table>

Summary

- Most patients with Parkinson disease (PD) have non-motor symptoms (NMS), and on average these can range from four to 19 different symptoms.
- NMS dominate the prodromal phase of PD and some may serve as clinical biomarkers of PD.
- NMS can be dopaminergic, non-dopaminergic, of genetic origin or drug induced.
- Clinical assessment of NMS should include the NMS Questionnaire (completed by patients) for screening, as recommended by the International Parkinson and Movement Disorders Society and other international societies.
- The total number of NMS in a patient with PD constitutes the NMS burden, which can be graded using validated cut-off scores on the NMS Questionnaire and Scale and can be used as an outcome measure in clinical trials.
- Despite NMS burden having a major effect on the quality of life of patients and carers, a large European study showed that NMS are often ignored in the clinic.
- The syndromic nature of PD is underpinned by non-motor subtypes which are likely to be related to specific dysfunction of cholinergic, noradrenergic, serotonergic pathways in the brain, not just the dopaminergic pathways.
- NMS can be treated by dopaminergic and non-dopaminergic strategies, but further robust studies supported by evidence from animal models are required.
- The future of modern treatment of PD needs to be supported by the delivery of personalised medicine.
The burden of non-motor symptoms

NMS has been studied using validated tools and cluster analysis in untreated de novo PD, early and advanced treated PD and multi-racial cohorts. \(^1\)\(^{15}\) The range of different NMS ascertained from these studies using the NMS Questionnaire is shown in Box 3. From a global perspective, the average number of NMS per patient varies from 4 to 19 compared with controls where the scores range from 2 to 12.\(^15\) Urinary dysfunction appears to be one of the most commonly reported NMS across several studies, followed by constipation, memory problems, anxiety and depression, fatigue and insomnia. Urinary dysfunction appears to be present throughout the spectrum of PD, being a particular challenge in the advanced palliative stage.

It is now recognised that rather than considering the effect of a single NMS, it is the total number of NMS present in a patient — the NMS burden — that determines quality of life.\(^16\)\(^,\)\(^17\) Globally, the rising number of people diagnosed with PD has a direct

2 Prodomal non-motor symptoms and potential risk of development of motor Parkinson disease (PD)

<table>
<thead>
<tr>
<th>Non-motor symptom</th>
<th>PD risk</th>
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</thead>
<tbody>
<tr>
<td>REM sleep behaviour disorder</td>
<td>80% progression to (\alpha)-synucleinopathy in approximately 10–12 years</td>
</tr>
<tr>
<td>REM sleep behaviour events</td>
<td>Polysomnography evidence of developing REM sleep behaviour disorder</td>
</tr>
<tr>
<td>Late-onset hyposmia/anosmia</td>
<td>Progression to motor PD</td>
</tr>
<tr>
<td>Episodic major depression</td>
<td>Prodromal PD feature</td>
</tr>
<tr>
<td>Constipation</td>
<td>Higher risk of developing PD</td>
</tr>
<tr>
<td>Excessive daytime somnolence</td>
<td>Higher risk of developing PD</td>
</tr>
<tr>
<td>Fatigue</td>
<td>Higher risk of developing PD</td>
</tr>
<tr>
<td>Abnormal colour vision/visual perception</td>
<td>Higher risk of developing PD</td>
</tr>
<tr>
<td>Erectile dysfunction</td>
<td>Higher risk of developing PD</td>
</tr>
<tr>
<td>Pain (often unilateral)</td>
<td>Pain often evident on side first affected at motor PD diagnosis</td>
</tr>
<tr>
<td>Cognitive impairment</td>
<td>Recent evidence of prodromal feature from PPMI cohort studies</td>
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</tbody>
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PPMI = Parkinson Progression Marker Initiative, REM = rapid eye movement.
consequential effect on the NMS burden, as NMS occur in virtually every patient with PD.\textsuperscript{3,4,15,16} The NMS burden has a direct inverse relationship with quality of life, and the frequent occurrence of NMS has led to attempts to revise our current understanding of PD (Appendix 1). Using multiple linear regression analysis, Martinez-Martin and colleagues showed that the correlation of quality-of-life measures in PD was stronger with NMS total score determined by the NMS Scale compared with motor symptoms and complications.\textsuperscript{4} International validation studies of the NMS Scale showed a highly significant inverse association with worsening quality of life and increasing NMS burden.\textsuperscript{7,19} Similar data have also been found with the NMS Questionnaire.\textsuperscript{8} In the late and palliative stage of PD, the impact of NMS is of great importance and contributes to hospitalisation and institutionalisation with high cost to society.\textsuperscript{20,21} A large scale naturalistic Italian study of over 1000 patients also confirmed that quality of life was significantly worse in those with NMS compared with those without NMS.\textsuperscript{17}

**Classification of non-motor symptoms**

NMS have non-dopaminergic and dopaminergic origins and vary widely in their nature, range and presentation.\textsuperscript{4} It is important not to regard all NMS together as a single entity, and sub-classification of NMS helps develop and deliver true personalised medicine strategies for PD. Classification of NMS based on source of origin has been attempted and is shown in Box 4.\textsuperscript{16,17}

**Neuropathology and animal models**

A range of pathophysiological mechanisms operate to start and continue the neurodegenerative process of PD (Box 5).\textsuperscript{4} Dysfunction in the dopamine pathways in the brain and periphery are a major problem, but other major neurotransmitters such as acetylcholine, noradrenaline and serotonin are also involved.\textsuperscript{4} Sometimes, the involvement of the non-dopaminergic pathways may be greater than dopaminergic involvement, supporting the concept of cholinergic, serotonergic and noradrenergic subtypes of PD.\textsuperscript{5,6,14,16} Braak and colleagues\textsuperscript{22,23} proposed six pathways of propagation of the pathological process in PD, commencing in the medulla and moving upwards. The proposal is based on Lewy body deposition in the brain. Stage one is associated with involvement of the olfactory bulb, anterior olfactory nucleus and the lower medulla. Stage 2 involves the lower brainstem containing non-dopaminergic nuclei such as the median raphe (serotonin) and locus coeruleus (noradrenaline) among many others. Neurodegeneration in these areas correlates clinically with late-onset hyposmia as well as RBD, which is now recognised as one of the key prodromal clinical biomarkers for the development of dementia as well as synucleinopathy, with over 80% risk of pheno-converting at 10 years.\textsuperscript{14} Hyposmia is included as a supportive criterion for diagnosis of PD.\textsuperscript{3} Stages 3 to 6 chart the progression of the pathological process of PD from the substantia nigra to the subcortical regions such as the basal ganglia and then the cortical area of the brain, the latter underpinning cognitive decline in advanced stages of PD.

The proportion of patients who go through all the pathological stages, and the rate of progression through these stages, is unclear. The progression pattern of PD varies and some patients may be reasonably active and independent even 20 years after the motor diagnosis of PD.\textsuperscript{25} Controversies surrounding the concept of advanced PD have recently been reviewed by Titova and colleagues.\textsuperscript{26} Broadly, however, most patients progress to advanced palliative stage by about 15 years after the onset of motor PD (with a variable length of prodromal period). Some initial clinical
biomarkers may suggest relatively rapid progression of PD and include patients with RBD and dysautonomia at the onset of the illness or those with early gait-related problems.

The peripheral nervous system, spinal cord as well as multiple viscera and skin are involved in PD and may express a range of NMS (Appendix 2).27,28 Neuropathology including α-synuclein deposition is seen in peripheral organs such as the heart, gut, submandibular glands and skin, indicating the widespread involvement of the peripheral nervous system in PD. The spread of α-synuclein deposition and consequent clinical non-motor effects have recently been reviewed by Jellinger.27 Peripheral tissue biopsy may emerge as a feasible biomarker for some specific NMS in PD, and skin biopsy has been proposed as a potential biomarker in RBD.14

To properly understand NMS in PD, robust animal models that express progressive neurodegeneration with Lewy body formation are required. Currently, there are no such models. Experimental animal models can assist in understanding the pathogenesis of the range of NMS, which in turn can help with potential approaches to their treatment. Knowledge of current developments in relation to attempts at producing animal models is therefore important to understand the pathophysiology of NMS in PD as well as to develop new treatments, currently a key unmet need. A list of potential animal models with a variety of NMS is shown in Appendix 3.29

**Non-motor symptom clinical measurement**

Holistic and widely validated tools such as the NMS Questionnaire30 and Scale31 are available and are recommended by the MDS. The NMS Questionnaire is a self-reporting tool completed by patients and is instrumental as a flagging tool in the clinic that is useful for epidemiological studies.

Holistic measurements of NMS are now supported by validation of the grading of burden using the NMS Questionnaire and Scale (Appendix 1). To ensure that the NMS status of patients with PD is assessed in parallel with their motor symptoms, recent reviews have recommended that the NMS assessment tools be used in combination with motor assessment (Hoehn and Yahr staging).33 A key recommendation would be to combine Hoehn and Yahr staging with the NMS Questionnaire grading for patients, performed at least once a year. A suggested paradigm for use in the clinic is shown in Box 6. Additional tools include the Unified PD Rating Scale, the Clinical Impression of Severity Index for PD, as well as a wearing-off questionnaire to address non-motor fluctuations. The Unified PD Rating Scale is the most widely used clinical scale for PD worldwide, and the Clinical Impression of Severity Index for PD has been specifically validated. Combined use for gradation strategies incorporating motor and non-motor measurements have been reviewed recently.34,35

**Non-motor fluctuations**

Non-motor fluctuations almost always accompany motor fluctuations and have been classified into autonomic, sensory and cognitive subtypes. Storch and colleagues36 have described NMS that are present exclusively during off periods, while others are present during on periods and worsen during off periods. Clinically, non-motor fluctuations usually manifest with anxiety, pain, drenching sweats, clouding of mind, fatigue and depression.

However, some NMS such as euphoria may occur exclusively during on periods.

**Non-motor subtyping**

Non-motor subtypes have been described using multidimensional cluster analysis studies in untreated patients and those with early PD. These report discrete clusters of patients expressing specific NMS.37,38 Clinical characterisation of these clusters

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**6 A proposed algorithm for a combined motor and non-motor assessment of non-motor symptoms (NMS) in the clinic to determine a patient’s non-motor status***

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**7 Factors that may drive or enable pathways for personalised and precision medicine in Parkinson disease (PD)**

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*All cut-off values quoted are validated from clinical studies. Rapid assessment in the clinic could be performed using Hoehn and Yahr motor staging and the self-completed NMS Questionnaire and subsequent burden grading. Adapted with permission from Katunina and Titova.25

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fatigue, sexual dysfunction, apathy, and urinary dysfunction, there is insufficient evidence of treatment.

### Personalised medicine

Personalised medicine is the modern way of delivering an individualised holistic PD treatment strategy.9,22 Personalised medicine thus encompasses several strands of treatment known as the enablers. From a pharmacological point of view, it should involve dopaminergic and non-dopaminergic strategies. In addition, there are sub-strategies involving precision and tailored medicine to suit the needs and requirements of individual patients. Precision medicine is relevant for patients who may be at risk of developing the clinical syndrome of PD as identified by specific gene mutations. Precision medicine in this scenario attempts to be preventive. Tailored medicine works with the single multi-factorial complex nature of PD to manage symptoms and develop subtype-specific strategies. Personalised medicine is now being applied to other conditions such as stroke, mental health, oncology as well as diabetes. In PD, neurotransmitter subtype-based individualised treatment can be considered. Patients with the cholinergic subtype could be treated by a combination of dopaminergic and cholinesterase inhibition therapy while also undertaking active counselling regarding lifestyle, job, exercise and freezing of gait.46 Patients with the noradrenergic subtype would require a focus on noradrenergic treatment for dysautonomia, whereas patients with serotonergic subtype fatigue could be managed by serotonin active drugs. However, robust clinical trials for such strategies are not available and trials are in progress.

Several factors influence the delivery of personalised medicine in PD (Box 7). A summary of pathways which may help deliver personalised medicine for PD is shown in Box 8. These range from genomic medicine to subtype/syndrome and symptom specific care.

### Conclusion

PD is a motor and non-motor disorder from the onset of the condition. Indeed, prodromal PD is largely non-motor. Key advances include the development of validated tools for holistic measurement of NMS, grading of the NMS burden, and a focus on multi-modal biomarkers to define non-motor PD subtypes. The latter is likely to lead to better management of NMS in PD. Future strategies should focus on developing robust animal models for specific NMS to provide a better understanding of the pathophysiology, which will enable development of personalised treatment strategies. The under-recognition of the burden of NMS and its effects can be remedied by better education of clinicians and caregivers. Only then will NMS cease to be the hidden painful face of PD.

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