A mobile-based system can assess Parkinson’s disease symptoms from home environments of patients

Treatment of Parkinson’s disease involves major challenges like the large within- and between-patient variability in symptom profiles as well as the emergence of motor fluctuations, which represent a significant source of disability in patients. In order to tackle this, there is a need for valid and frequent measurements about symptoms in relation to different treatment interventions. At Högskolan Dalarna, the Lecturer Mevludin Memedi has developed a telemetry system that assesses symptoms via analysis of self-assessments and motor tests to facilitate the management of PD.

**Parkinson’s disease (PD)** is a neurodegenerative disorder of the central nervous system that is associated with a number of motor and non-motor symptoms. The major motor symptoms of the disease include bradykinesia (slowness of initiating voluntary movements), rigidity (increased muscle tone), tremor (a 3–5 Hz tremor at rest) and impaired postural stability. A challenge for the clinical management of PD is the large within- and between-patient variability in symptom profiles as well as the emergence of motor complications, which reduce the patients’ health-related quality of life. The main complications are insufficient levels of medication leading to common PD symptoms and excessive levels of medication leading to abrupt, involuntary movements also known as dyskinesias.

PD motor symptoms and motor complications are most commonly evaluated during clinical visits through the use of clinical rating scales like the Unified Parkinson’s Disease Rating Scale (UPDRS) and the 39-item PD questionnaire (PDQ-39). Although these in-clinic rating scales have proved to be useful in quantifying the severity of symptoms, their main limitation is related to the low resolution of assessments by providing a momentary snapshot of the clinical condition. In addition, these scales may need to be filled out by trained clinicians during a clinic visit, which in turn is experimental and may not accurately represent the activities of patients in their home environment.

IT-based methods for collecting, summarizing and visualizing symptom data can be useful in this context. In contrast to the in-clinic scales, these methods are useful for detecting subtle symptom changes as well as providing objective (observer-independent) measures that can be repeated at multiple time points. This article presents the development and evaluation of computer-based methods for automatic and remote monitoring of PD symptoms, using repeated measures collected by means of a telemetry touch screen device. A summary of different studies and results can be found below. The summary was published in entirety as part of the doctoral thesis entitled “Mobile systems for monitoring Parkinson’s disease” at the School of Science and Technology, Örebro University1.

**Patients and Methods**

The results presented in this article are based on data from two clinical studies, both of which were approved by the relevant agencies and written informed consent was given. In total, 95 patients in different clinical stages of PD and 10 healthy elderly (HE) subjects were asses-
sed (Table 1). Sixty-five patients with advanced PD were recruited in an open longitudinal 36-months study at nine clinics around Sweden. On inclusion, 35 of the patients were treated with levodopa-carbidopa intestinal gel (LCIG, hereafter denoted as LCIG-non-naïve) and 30 patients were candidates for switching from oral treatment to LCIG (hereafter denoted as LCIG-naïve). Thirty patients in Milan, Italy, who had a clinical diagnosis of idiopathic PD participated in a second study.

Both patients and HE subjects performed repeated, time-stamped and remote assessments of their subjective and objective health indicators using a telemetry test battery implemented on a touch screen handheld device. On each test occasion, patients were first asked to answer seven PD-related questions and then to perform a set of upper limb motor tests including tapping and tracing spirals on the screen of the device.

Figure 1. A photograph of the telemetry test battery. The test battery consisted of a patient diary section for collecting self-assessments of symptoms and a motor test section (tapping and spirography) for collecting objective measures of upper limb motor function.
The evaluation of the system was done in two stages: first presenting and demonstrating its functionalities to an advisory board consisting of neurologists and to nurses who had experience using the telemetry device during the clinical study period. A second evaluation determined the level to which nurses were satisfied with the usability of the system by administering a standard questionnaire.

RESULTS
The method for scoring the drawing impairment in spirals correlated well with the visual ratings of spirals given by two neurologists with a Spearman rank correlation coefficient of 0.89 (p<0.001). In addition, the method had good test-retest reliability indicating a good stability of its scores over time. The method for automatic assessment of alternating tapping performance of patients had good validity, internal consistency and sensitivity to treatment changes. In addition, the method was able to discriminate between patients in different stages of PD and HE subjects as well as its scores significantly differed among categories of the UPDRS motor scale measuring upper limb motor performance (Figure 2).

The objective measures of upper limb motor function could discriminate between motor states among patients; tapping speed reflected Off symptoms whereas spatial irregularities during spirography reflected dyskinesias.

The six symptom dimensions of the test battery had a good internal consistency with a Cronbach’s alpha coefficient of 0.81. The OTS correlated well with total UPDRS and total PDQ-39 scores with a coefficient of 0.59.
9. In the case of LCIG-naïve patients, the mean OTS improved to the first test period on LCIG treatment and this improvement remained significant until month 24 (Figure 3). The maximum improvement was seen at month 3 with 0.15 units (32%, p<0.001) higher than at baseline.

In the case of evaluation of the web-based system, eleven of the 14 neurologists had a positive impression, 1 had a neutral impression and 2 had a negative impression. The responses of the nurses can be summarized in a qualitative manner as follows: the web-based system is very useful, the results during the test periods showed agreement with qualitative observations of the patient e.g. "one patient was in a bad condition at baseline, he improved after starting LCIG, then he became better again, 24-h infusion started and the patient became better again; we can clearly follow this change in the system, comparisons between patients are possible, that is one patient is in better/worse condition than another". Responses to the questionnaire were mixed; a majority of the nurses were quite satisfied with the usability although a sizeable minority was not.

**DISCUSSION**

Methods for assessing the severity of symptoms and treatment-related complications are crucial for effective clinical management of PD. Relevant tele-
medicine approaches to remote monitoring of PD motor symptoms and motor complications include e-diaries, wearable inertia sensor systems, various testing tools and video-based monitoring systems. The objective methods for quantifying the symptom severity can potentially complement and enhance both clinician and patient perspectives. Objective assessments may better help to capture symptom severity and fluctuations as compared to using conventional rating scales which are subject to clinical judgment and bias. In this article the use of IT-based methods was explored in order to develop a system architecture, consisting of computer-based methods for assessments of symptoms and the software around this platform, for providing an effective alternative to management of PD.

The methods for assessing the severity of upper limb motor impairments during alternating tapping and spirometry were evaluated as being feasible approaches for quantitative and objective assessment of symptoms. The methods were designed and tailored for long-term telemetering of symptoms as well as had good level of clinical interpretability. Both the methods provided means for deriving objective measures of symptom severity, which in turn can be used as valid outcomes in clinical trials for remote evaluation of upper limb motor function of patients. Although the methods were good at reflecting the severity of symptoms, the methods could not detect and measure properties, which are typical for movement patterns exhibited during under- and over-medicated motor states that is Off and dyskinesia, respectively. In order to accomplish this, one idea is to gather simultaneous and multidimensional movement data using wearable sensors and test battery and then to map their movement data using wearable sensors and test battery during alternating tapping and spirometry were evaluated as being feasible outcome measures for long-term and remote monitoring of PD symptoms. The internal consistency among the dimensions was good indicating that they measure the same construct of symptom severity. In addition, the OTS correlated well with total UPDRS and total PDQ-39 scores as well as was sensitive to treatment changes and could reflect the natural PD progression over time in advanced Swedish patients. In general, using an OTS may facilitate the patient screening process and help avoiding sub-optimization of treatments. The OTS could also be beneficial for deciding if a treatment change leads to an improvement of a patient’s general condition or not.

The results from the usability evaluation of the web-based system showed that the information presented was comparable to qualitative clinical observations of the nurses who had experience using the telemetry device during the Swedish study. In addition, from the demonstration of its functionalities to the neurologists it was concluded that using the system assists in identifying patients who are not doing well and facilitates follow-up optimization of an individual patient’s treatment. The system was seen as most important for fluctuating patients and for regional patients i.e. patients living in regions far away from a clinic and can be considered as a tool that will assist in the management of patients.

In summary, despite the efficacy of the currently available telemedicine systems, their effectiveness in routine clinical practice has yet to be established and should be widely adopted. Many aspects including validity, reliability, security and privacy, usability and acceptability must be considered before they can be applied routinely.

The OTS and the six symptom dimensions of the test battery were evaluated as being feasible outcome measures for long-term and remote monitoring of PD symptoms. The internal consistency among the dimensions was good indicating that they measure the same construct of symptom severity. In addition, the OTS correlated well with total UPDRS and total PDQ-39 scores as well as was sensitive to treatment changes and could reflect the natural PD progression over time in advanced Swedish patients. In general, using an OTS may facilitate the patient screening process and help avoiding sub-optimization of treatments. The OTS could also be beneficial for deciding if a treatment change leads to an improvement of a patient’s general condition or not.

The results from the usability evaluation of the web-based system showed that the information presented was comparable to qualitative clinical observations of the nurses who had experience using the telemetry device during the Swedish study. In addition, from the demonstration of its functionalities to the neurologists it was concluded that using the system assists in identifying patients who are not doing well and facilitates follow-up optimization of an individual patient’s treatment. The system was seen as most important for fluctuating patients and for regional patients i.e. patients living in regions far away from a clinic and can be considered as a tool that will assist in the management of patients.

In summary, despite the efficacy of the currently available telemedicine systems, their effectiveness in routine clinical practice has yet to be established and should be widely adopted. Many aspects including validity, reliability, security and privacy, usability and acceptability must be considered before they can be applied routinely.

**REFERENCES**


