Detection of hand tremor in patients with Parkinson's disease using a non-invasive laser line triangulation measurement method

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ABSTRACT

Detection of hand tremor for evaluating and diagnosing early stage of Parkinson's disease (PD) remains a challenge. The purpose of this study was to correlate hand tremors analyzed by a non-invasive method with clinical manifestations among patients with PD. Four different modes of tremor detection in patients with PD were detected individually using a laser line triangulation measurement (LLTM) method and off-line analyzed.

The results showed a significant correlation between age at disease onset and tremor frequency obtained from the left hand and from the non-dominant hand. Furthermore, there was a significant positive correlation between disease duration and tremor frequency obtained from the left hand and from the non-dominant hand using different detection modes.

We conclude that the laser line triangulation measurement is a non-invasive, non-contact, portable, easy-to-use and low cost method that can detect tremor early in the course of patients diagnosed with PD.

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1. Introduction

Parkinson's disease (PD) is a common progressive neurological disorder that typically begins about age 60 and characterized mainly by resting tremor, rigidity, and bradykinesia [1]. In the early phase of PD, some motor and particularly non-motor signs may emerge several years before a diagnosis is made. It is conceivable that it might be possible to start an effective neuroprotective therapy before an advanced stage of the disease is reached. In this context, the identification of patients at an early stage of the disease would be essential for any successful neuroprotection.

Both pathology and imaging studies have shown that patients with PD have a prolonged period during which their vulnerable neuronal populations are degenerating, when typical motor symptoms have not yet developed [2,3]. First imaging signs that affect the substantia nigra obtained by positron emission tomography (PET) and Single-Photon Emission Computed Tomography (SPECT) are detectable before a definite clinical diagnosis is made [4]. Although biomarkers such as hyperechogenicity of

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the substantia nigra [5–7] as well as premotor symptoms like olfactory dysfunction [8], behavior disorders [2,9] and neuropsychological impairment [7,10], have been used to indicate vulnerability to PD, their specificity needs further elucidation.

Tremor, one of the cardinal signs of PD, is defined as an involuntary, rhythmic, and sinusoidal movement of one or more body parts [11]. Although different forms of tremor may be seen with PD, about 50% of patients with PD have resting tremor as an initial manifestation of the disease. Hence, resting tremor is generally regarded as a characteristic of PD [12,13]. There is consensus that Unified Parkinson's disease rating scale (UPDRS) is a universal scoring system for symptoms evaluation in PD patients, nonetheless, tremor scoring in UPDRS is only on semi-quantitative scale [14]. Several methods for the measurement of tremor have been developed these last decades. Conventional approaches frequently used in measurement and analysis of tremor [15] including Electromyography (EMG), motion transducers such as accelerometry [16,17], gyroscope [18], and the spirogram with digitizing tablets [19] . Although Electromyography (EMG) provides additional useful information about the activity of muscles involved in the generation of tremor, the application is still limited due to its invasiveness [20]. Accelerometry or gyroscope is another assessment of kinematics for tremor. However, the acquiring data may be difficult to be appreciated clinically because sinusoidal motion like tremor is not easily perceived in accelerometric or rotational units [20] and there is still no validated analytic model to distinguish between data from accelerometers due to acceleration and gravity [21]. Gyroscopes are considered as presenting long term stability except the defect that presence of a low frequency bias, mainly due to temperature effects [21]. Spiral analysis is a graphonometric method of measuring upper limb kinematics by analyzing Archimedean spirals drawn on a digitized graphics tablet [22]. Nevertheless, it developed with considerable expenditure and is highly sophisticated concerning further data handling and evaluation in particular [23]. Videos can be used to evaluate the symptoms of patients with Parkinson's disease. However, the videotaped motor examination may present some limitations when patients have mild symptom and the data analysis of videos may need to be exerted by the experienced expert for validity [24]. Besides, most other equipment used for detecting tremor is either prohibitively expensive or may interfere with the measurement results due to the necessity of physical contact.

Therefore, the development of a non-invasive, easy to apply, quantifiable method that is able to measure the degree of tremor is important for the early diagnosis of PD.

Laser line triangulation is a well-known method used for thickness and profile measurements and is already used in many industrial fields [25,26]. The laser line triangulation line measurement method can measure not only very small amplitude (10 μm resolution) vibrations but also vibration in different local regions simultaneously [27] . Different tremors have characteristic local frequencies, and in humans the resting tremor of PD generally occurs in the 3–7 Hz frequency range [28,29]. In our previous study [27], we described the development of a

triangulation laser line method to detect hand tremor in Parkinson patients. This non-invasive, non-contact, portable, easy-to-use and low cost measurement system combines Fast Fourier Transformation (FFT), the centroid method, and the optical triangulation method. Using this approach, microvibrations of the human hand can be measured with a resolution down to 10 μm. However, the correlation between data obtained from this method and clinical manifestations remains further elucidation. The purpose of the study was to correlate hand tremors analyzed by this novel method with the clinical manifestation in Parkinson patients.

2. Methods

2.1. Subject recruitment

Subjects were recruited from the neurological clinic of Taipei Veterans General Hospital. The study protocol was approved by the Institutional Review Board of the same hospital. PD was diagnosed by a neurologist according to the core assessment program for intracerebral transplantation (CAPIT) [30] and the severity of PD was assessed according to the Hoehn and Yahr scale [31].

Inclusion criteria were age > 55 years old, Hoehn and Yahr Stage I or II and being diagnosed at least 6 months earlier with the disease before entry into the study. A stable PD medication regimen, such as Madopar, Pramipexole, Sinemet or Stalevo, for at least 30 days before entry into the study was given. Medication during the study period was one of the confounding factors in this study. However, we detected tremor before intervention with traditional Chinese medicine, so that all these patients were in stable medication regimen. Exclusion criteria included: (1) prior history of severe cardiac, renal, liver and endocrine disease; (2) prior history of stroke or dementia; (3) skin infection affecting the detection area; (4) laser or dark phobia; (5) inability to finish the experiments. All subjects gave informed consent and were assessed using the Unified Parkinson's disease rating scale (UPDRS) and the Schwab and England rating of activities of daily living by a trained neurological nurse prior to data collection.

From Dec. 2008 to Nov. 2011, eighteen patients, thirteen males and five females, who met the criteria were enrolled in this study and received the four modes of alternative hand tremor measurements. However, there were four males and one female withdraw after informed consent and assessed using the UPDRS and the Schwab and England rating of activities of daily living. One 79 years-old subject have only completed mode 2 (both resting hands mode) assessment due to weakness. Two males and one female failed to complete mode 3 (single postural hand mode) and mode 4 (both postural hand mode).

2.2. Device and experimental setup

The optical non-contact measurement device consisted of a laser projector with a 1.3 mW laser diode (Model no. QL63d5sA, MORETEC, Inc.) and a complementary