Automatic spiral analysis for objective assessment of motor symptoms in Parkinson’s disease

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OBJECTIVE

To develop a method for objective quantitative assessment of PD motor symptoms related to OFF episodes and peak dose dyskinesia, using spiral data gathered by using a touch screen telemetry device. The aim was to objective characterize predominant motor phenotypes (bradykinesia and dyskinesia), to help in automating the process of visual interpretation of movement anomalies in spirals as rated by movement disorder specialists.

BACKGROUND

A retrospective analysis was conducted on recordings from 65 patients with advanced idiopathic PD from nine different clinics in Sweden, collected from January 2006 until August 2010 [1]. In addition to the patient group, 10 healthy volunteers were also recruited using a similar procedure. The primary outcome measure was the UPDRS III rating scale. The data collection period for the patients was 1-2 weeks and for the healthy volunteers, one session. The data was pre-processed to obtain a touch screen telemetry device output. The recordings were performed four times per day during waking and nocturnal periods. On each test occasion, the subjects were asked to trace pre-drawn algorithms depicted on the screen of the device. The trials were conducted in a controlled setting with the patient seated, with the arms resting on the table. The video data was recorded from the hand of the dominant hand during the session, using the hand-drawn spiral. The spiral was shown on the screen of the device. The spiral was repeated three times per test occasion and they were instructed to complete it within 30 seconds. The device had a sampling rate of 10Hz and measured both position and orientation (in 0.01 degrees) of the pen.

METHODS

Four independent raters (FB, DH, DI, and DH) used a web interface that annotated the spiral drawings and allowed them to observe different kinematic features during the drawing process and to rate task performance [2]. Initially, a number of kinematic features were included including ‘impairment’, ‘speed’, ‘irregularity’ and ‘hesitation’ followed by marking the predominant motor phenotype in a 3-category scale: bradykinesia, dyskinesia or mixed phenotype. The raters rated the predominant phenotype on a 3-category scale: tremor, bradykinesia and dyskinesia. When assessing the two main motor phenotype categories (bradykinesia or dyskinesia) in animated spirals the agreements between the four raters were as follows: ‘impairment’ (bradykinesia = 0.75, dyskinesia = 0.69), ‘speed’ (2.5, 0), ‘irregularity’ (2, 2.75) and ‘hesitation’ (2, 2.75). The data was further processed to identify the predominant motor phenotype (bradykinesia and dyskinesia) and/or treatment-induced symptoms (dyskinesia). A Principal Component Analysis was applied on the features to reduce feature dimensions where 4 relevant principal components (PC) were retained and used as inputs to the MLP classifier. Finally, the MLP classifier mapped these components to the four raters. To automate the process of scoring the bradykinesia and dyskinesia in PD patients whilst they draw spirals using the touch screen device. For motor phenotype (bradykinesia vs. dyskinesia) classification, a support vector machine (SVM) was used, the stratified 10-fold cross validation technique was employed.

RESULTS

There were good agreements between the four raters when rating the predominant kinematic features with intra-class correlation coefficient (ICC) ranging from 0.66 to 0.78 for bradykinesia and 0.60 to 0.72 for dyskinesia or moderate agreements when rating ‘hesitation’ with an ICC of 0.49. When assessing the two main motor phenotype categories (bradykinesia vs. dyskinesia) in animated spirals, the agreements between the four raters ranged from fair to moderate (Table 1). There were good correlations between mean visual ratings of the four raters on different Y axis scales for the two cases. Mean visual ratings of the four raters when rating ‘speed’ varied from 1.83 (0) to 2.75 (4) for impairment, ‘speed’, ‘irregularity’ and ‘hesitation’ followed by marking the predominant motor phenotype in a 3-category scale: bradykinesia, dyskinesia or mixed phenotype. The raters rated the predominant phenotype on a 3-category scale: tremor, bradykinesia and dyskinesia. When assessing the two main motor phenotype categories (bradykinesia or dyskinesia) in animated spirals the agreements between the four raters were as follows: ‘impairment’ (bradykinesia = 0.75, dyskinesia = 0.69), ‘speed’ (2.5, 0), ‘irregularity’ (2, 2.75) and ‘hesitation’ (2, 2.75). The data was further processed to identify the predominant motor phenotype (bradykinesia and dyskinesia) and/or treatment-induced symptoms (dyskinesia). A Principal Component Analysis was applied on the features to reduce feature dimensions where 4 relevant principal components (PC) were retained and used as inputs to the MLP classifier. Finally, the MLP classifier mapped these components to the four raters. To automate the process of scoring the bradykinesia and dyskinesia in PD patients whilst they draw spirals using the touch screen device. For motor phenotype (bradykinesia vs. dyskinesia) classification, a support vector machine (SVM) was used, the stratified 10-fold cross validation technique was employed.

CONCLUSIONS

The proposed method quantitatively assessed the severity of unwanted symptoms and could reasonably well discriminate between PD-specific (bradykinesia) and/or treatment-induced motor symptoms, in relation to visual assessment of movement disorder specialists. The objective assessments could provide a time-effect summary score that could be useful for improving decision making during evaluation of individualized treatment when the goal is to maximize functional On time for patients while minimizing their Off episodes and troublesome dyskinesia.

REFERENCES


Table 1. Weighted Kappa statistics for the four classifiers and four raters. The motor phenotype (bradykinesia and dyskinesia) was rated in animated spirals. Area under the curve (AUC) statistics are highly significant (p<0.001)

Table 2. Absolute intraclass correlation coefficient (ICC) statistic level between the first and second test trials of the first (a) and second (b) four raters' signatures. Black diagonal indicates perfect ICC statistic level. Significance level: * p<0.05; ** p<0.01; *** p<0.001, n.s. = not significant.

Figure 1. Two illustrative examples of spirals rated as bradykinetic (upper row) and dyskinetic (lower row) by the four raters. The first column shows the actual spiral images of the four PCAs across the three spiral test trials. The second column shows the high-frequency wavelet coefficients (significance level: * p<0.05; ** p<0.01; *** p<0.001).