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Digital movement analysis, a new objective method of measuring tardive dyskinesia and drug-induced parkinsonian tremor: acceptability, reliability and validity

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Abstract Digital movement analysis (DMA) is a new instrumental approach to assessing oral tardive dyskinesia (TD) by means of digital image processing of a video signal, tracking five paper dots placed around the patient's mouth. A total of 40 schizophrenic patients, 30 with and 10 without TD, were examined twice (with a 3-month interval) with this new device. The patients were further examined with two TD rating scales: the St. Hans Rating Scale for extrapyramidal syndromes (SHRS) and the Abnormal Involuntary Movement Scale (AIMS).

The schizophrenic patients accepted the instrumental assessment without any anxiety or resistance. The internal reliability of the apparatus was high, with correlation coefficients of 0.80–0.99. The DMA TD values correlated with the SHRS and AIMS scores with correlation coefficients of 0.48–0.73 indicating an acceptable, although not strong, concurrent validity. Fluctuations occurred from the first to the second examination independent of medication. For these fluctuations no correlation was found between DMA values and rating scores. Finally, the DMA device was able to detect perioral tremor as a sign of parkinsonism.

It has been concluded that DMA is a useful supplement to classical TD rating, although further validity evaluation is warranted.

Key words Tardive dyskinesia · Movement disorder · Parkinsonism · Instrumental assessment · Digital image processing

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Introduction

Tardive dyskinesia (TD) is a potentially irreversible side effect seen in an average of 20% of schizophrenic patients treated with neuroleptic drugs for a longer period of time (Kane and Smith 1982; Gerlach and Casey 1988; Jeste and Caligiuri 1993). Tardive dyskinesia consists of involuntary movements, mainly in the oral region (jaw movements and tongue protrusions), but also in other parts of the body, especially the hands and feet (Gerlach 1979).

Evaluation of TD has been done in a number of ways, which can be divided into tree main groups (Gardos et al. 1977):

1. Instrumental assessments
2. Clinical rating scales (both global and multi-item)
3. Frequency counts

Proposed methods of instrumental approaches to measure TD and parkinsonism of the oral region in resent years include: vocal assessments (Fann et al. 1977), electromyography (Jus et al. 1973), electromechanical instruments such as the pneumatic piezoelectric transducer system (Denney and Casey 1975) and ultrasound (Resek et al. 1981).

The instrumental approaches have the advantage of being objective. Usually, the numeric results of the different devices are easy to handle statistically. The disadvantages are that the patient has to be brought to the laboratory and may be disturbed by the apparatus used for measurement. Furthermore, information is only obtained from the body part which is measured. The instrumental methods have not gained widespread use, although the ultrasound technique has been used in a few clinical studies (Olivieri et al. 1990; May et al. 1983).

Rating scales have the advantages of a global approach, simplicity of performance and clinical relevance. Establishing good reliability through training is mandatory.

Frequency counts are simple and easy to handle statistically. The disadvantages include that only one body part can be counted at a time, and that the particular movements counted may not correspond to the overall severity

of the condition because the counting does not tell anything about the amplitude, magnitude and disabling nature of the abnormal movements present. The method has not been used on a larger scale.

The purpose of this study was to evaluate a new instrumental device to measure TD. The instrument utilizes image processing of a video signal for digital movement analysis (DMA) in the assessment of oral TD (jaw and lip movements). More specifically, the aims were to:

1. Examine the practical usefulness and acceptability of DMA in an investigation of TD in psychotic patients
2. Evaluate the internal test-retest reliability of the apparatus
3. Analyze its concurrent validity in comparison with established rating scales for dyskinesia: Abnormal Involuntary Movements Scale (AIMS) (Guy 1976) and the St. Hans Rating Scale for Extrapyramidal Syndromes (SHRS) (Gerlach et al. 1993)
4. Evaluate its ability to detect the coexistence of drug-induced parkinsonian tremor in TD patients.

Materials and methods

Patient sample and design

The patients (30 with and 10 without *oral* dyskinesia) were selected from the population of psychotic patients at St. Hans Hospital. Inclusion criteria were: age above 18 years, a diagnosis of schizophrenia according to DSM-III-R, a total oral TD score (tongue-jaw) above zero on the SHRS for the 30 TD patients and 0 for the 10 non-TD patients, and treatment with a neuroleptic of any kind at a constant dose for at least 3 months. Anticholinergics, benzodiazepines and antiepileptics were allowed. Forensic patients and patients with known organic disorders, drug of alcohol abuse, were not included in the study. Informed consent was obtained from all patients, and the study was performed according to the principles of the Helsinki and Hawaii declarations.

Of the 40 patients, 20 were inpatients, 14 were day patients and 6 were outpatients; 30 were males and 10 were females. The mean age was 51 years (range 19–79 years), and mean duration of illness was 20.1 years (range 1–37 years). The intensity of the psychosis was measured by means of the Positive and Negative Syndrome Scale (PANSS) (Kay et al. 1989; Knorring et al. 1992), which gave the following results: total positive symptoms 19.3 (range 7–40); negative symptoms 19.5 (range 9–35); general symptoms 38.0 (range 21–68); total PANSS score 76.7 (range 40–130).

The following neuroleptics were given: *cis*(Z)-zucloclopenthixol 16 patients, perphenazine 5, clozapine 6, haloperidol 5, *cis* (Z)-flupenthixol 3, sulpiride 2, penfluridol 1, thioridazine 1 and pipothiazine palmitate 1. A total of 25 patients received anticholinergic drugs. In the group of TD patients the mean duration of TD was 8.4 years (range 0.5–24 years).

A total of 29 patients received benzodiazepines in low doses, 10 as a hypnotic and 19 as an anxiolytic. Two patients received antiepileptic drugs, and 2 lithium carbonate (plasma level 0.5–0.8 mEq per litre).

The patients were examined twice with a 3-month interval. In the period between the evaluations, the patients were treated according to the usual principles of the department and by their usual doctors regardless of this investigation.

All 30 schizophrenic patients with oral TD and 10 schizophrenic patients without oral TD completed the first assessment with the DMA device and the two rating scales, SHRS and AIMS. A total of 26 TD patients and 9 non-TD patients completed the second examination. For various reasons unrelated to the study, 5 patients were unable to participate in the second examination.

From the first to the second assessment only minimal changes occurred in neuroleptic medication. The dosage was slightly raised in 7 cases and slightly lowered in 3. Two patients changed the neuroleptic drug, but received an equivalent dose. A total of 23 patients received unchanged medication (marked in Table 1). A total of 26 patients received anticholinergic drugs during both examinations; no changes in dose occurred.

Evaluation

Test – retest of apparatus

To evaluate the internal reliability of the DMA device a re-run of ten consecutive recordings was made from the backup tapes. The new API values were correlated to the original API values made during the recording sessions.

DMA recording

After a brief general clinical interview, mainly to put the patient at ease, but also to achieve basic demographic data, the DMA recording was made.

The recording took place in a darkened room. The subject was sitting in a comfortable armchair with a good headrest. In front of the subject a normal television was placed to show a videotape (of classic ballet themes). Five paper dots approximately 5 mm in diameter with yellow flourocence (made with a text marker) were attached by skin cream: one to the tip of the nose (as a point of reference to correct for head movements) and four around the mouth, 1 cm above and below the angles of the mouth on both sides (see Fig. 1). An ultraviolet light bulb of 18 W was placed above the television to illuminate the dots.

Before recordings started, the subject was allowed to watch the video tape for a few minutes for acclimatization. The subject was instructed not to talk and not to move his/her head during the recordings. Two different sessions were recorded in standardized routine during the same succession:

1. Subjects were asked to concentrate on the music and watch the video tape (called RELAX).
2. At irregular intervals the sound of the video was muted. Subjects were asked to acknowledge the vanishing of the sound by pressing a button on a remote control held in hand, upon which the sound returned (called TASK).

Each of the two settings was recorded for 5 min. An observer was present to monitor for subject-generated artefacts (i.e. talking or sneezing). If artificial movements occurred during the recording, time and duration were noted to cut them out afterwards. All recordings were on-line processed by the computer and simultaneously recorded on videotape (for backup copy).

A detailed description of the device is presented by Gattaz and Büchel (1993). In brief, the apparatus consists of a normal video camera, a frame grabber with a signal processer in a standard personal computer (IBM-compatible) and software (Fig. 1). The images from the camera are digitized by the frame-grabber board to make the computer's software able to trace and analyse the movements of the five bright dots placed on the subject's face. The coordinates of the points are extracted and stored in the PC hard disk automatically. The resulting curves are further analyzed by Fourier transformation to obtain a frequency spectrum of the sampled data.

To achieve a reliable value of the total energy in different frequency bands (band here means frequency intervals, e.g. the spectrum from 1 to 3 Hz, 2 to 6 Hz, etc.) the computer calculates average power indices (API) for the designated bands. The TD movements are predominantly in the 1–3 Hz band, which is therefore used in the present study, while parkinsonian tremor is best seen in the 3–6 and 4–7 Hz band (Gattaz and Büchel 1993). The API value reveals the mean energy of vertical and horizontal movements in the defined frequency band. It is a unitless entity that can be interpreted as the relative magnitude of movements.

Table 1 Dyskinesia scores of 10 schizophrenic patients without oral tardive dyskinesia (TD) and 30 schizophrenic patients with oral TD, classified according to an increasing oral TD score (Oral-A, 1. exam). The dyskinesia scores are given as API (Average Power Index) values and as St. Hans Rating Scale scores

Patient nr.	API values in 1-3 Hz band						St. Hans Rating Scale Scores					
	1. examination			2. examination			1. examination			2. examination		
	Relax	Task	Mean	Relax	Task	Mean	Oral-P	Oral-A	Total-TD	Oral-P	Oral-A	Total-TD
1*	14	15	15	23	23	23	0	0	0	0	0	0
2*	27	23	25	35	23	29	0	0	0	0	0	0
3	28	26	27	30	31	31	0	0	0	0	0	0
4	39	26	33	39	52	46	1	0	1	0	0	0
5*	34	27	31	32	24	28	0	0	2	0	0	1
6	30	29	30				0	0	0			
7	26	31	29	42	62	52	0	0	0	0	0	2
8*	24	31	28	56	58	57	0	0	0	0	1	1
9	33	36	35	37	36	37	0	0	1	0	0	0
10*	30	39	35	22	30	26	0	0	0	0	0	0
11*	21	27	24	26	32	29	0	1	2	0	0	2
12*	36	35	36	41	39	40	0	1	2	3	2	7
13*	29	25	27	23	24	24	0	2	2	0	2	2
14*	23	26	25	25	30	28	0	2	3	0	0	1
15*	29	30	30	33	36	35	1	2	3	1	1	6
16	34	35	35	40	38	39	0	2	2	1	1	3
17	35	40	38	26	35	31	1	2	3	0	1	1
18	60	49	55	49	52	51	0	2	2	0	2	2
19	57	49	53	42	37	40	2	2	5	5	3	8
20*	73	59	66	41	58	50	1	2	3	3	4	5
21*	70	61	66	45	54	50	0	2	1	0	1	1
22*	33	70	52	30	47	39	2	2	8	0	1	5
23*	21	26	24	26	25	26	0	3	6	0	3	5
24*	23	35	29	30	46	38	0	3	4	0	1	1
25	35	41	38				1	3	4			
26*	61	46	54	54	45	50	3	3	6	1	2	6
27*	41	55	48	43	61	52	0	3	6	1	5	7
28	68	69	69				3	3	7			
29	30	36	33	40	66	53	0	4	3	3	5	6
30	27	51	39	70	47	59	1	4	5	4	5	5
31	39	42	41				2	5	4			
32*	31	55	43	46	90	68	5	5	8	6	5	9
33	75	61	68	51	50	51	4	5	10	4	8	13
34*	78	77	78	53	46	50	4	5	5	4	5	5
35*	35	85	60	39	53	46	0	5	4	2	4	5
36*	44	69	57	87	89	88	4	6	8	7	7	14
37*	38	75	57	62	44	53	6	6	9	4	3	6
38	78	85	82				1	6	6			
39*	72	164	118	58	99	79	5	6	18	5	8	21
40	78	47	63	92	45	69	4	7	10	2	6	8
MEAN	41	48	45	43	46	45	1,3	2,6	4,2	1,7	2,5	4,7

Abbreviations: *Oral-P* oral TD score when the patient is passive; *Oral-A*: oral TD score when the patient is activated; *Total-TD* total TD score

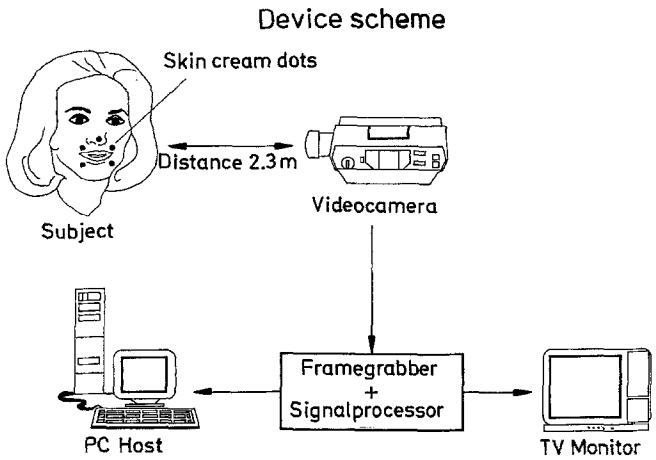

Fig. 1 The device for assessments of tardive dyskinesia by means of digital image processing

Rating scales

Immediately after the DMA recording, a standardized video recording of the patients' extrapyramidal symptoms was made in another room. A simultaneous recording of the face during the DMA recording would have been optimal, but was not possible because of the darkened room (following termination of this study the device has been improved, so it is now possible to make recordings in clear room with white light). The videotape was used for later blind evaluation by means of SHRS and AIMS.

The AIMS and SHRS are multi-dimensional rating scales designed to quantify the severity of extrapyramidal syndromes. AIMS assesses dyskinesia only, whereas SHRS contains sections for the evaluation of dyskinesia (eight items), parkinsonism (eight items), akathisia (subjective and objective) and dystonia, all of which are essential in any complete rating of dyskinesia patients (Gerlach and Casey 1988). AIMS uses scores of 0–4, whereas SHRS uses a scale from 0–6. The SHRS dyskinesia scale consists of a passive and active part. The patients are evaluated in two situations: when they are sitting and relaxed ("passive") and when they are activated by standardized voluntary movements, which often unveil dyskinesia ("active").

Statistical procedure

For test-retest analyses the Pearson correlation coefficient was used. For validity the Spearman rank-order correlation test was used because a non-normal Gaussian distribution was assumed. To discriminate between clinical groups, 95% confidence intervals were used.

Results

EPS characteristics

Table 1 shows the dyskinesia data for each of the 40 patients, both DMA values and the most essential SHRS scores. Oral TD is defined as a score above 0 in the "active oral" score (jaw plus lips) of the SHRS. The ten patients with no oral dyskinesia are shown at the top of the table. It can be seen that some of these patients had questionable/mild dyskinesia in other parts of the body (total scores 1 or 2).

Of the 30 patients with oral TD, two scored 1, ten scored 2 and the remaining 18 patients scored 3 or above. As to the global scores, 20 patients had mild TD (score 1–2) and 10 moderate moderate-to-severe TD (score 3–4). A total of 20 patients had parkinsonian symptoms (total parkinsonian score > 5). No patients had dystonic features. Motor akathisia (score ≥ 1) was seen in 25 patients, and psychic akathisia (score ≥ 1) in 19 patients.

Acceptability of examination procedure

Although the patients included were psychotic, they had no problems in cooperating in the examination with the DMA, and in participating in both first and second examination. There was no anxiety due to the equipment. There were no objections to having the five paper dots placed on the face or to being in a darkened room watching television, or to cooperating in the TASK session. Only twice did watching television cause problems for the patients, because of psychotic symptoms. The problem was solved by dimming the light without turning off the sound and instructing the patient to watch the darkened screen (which was not turned off, only blurred). The ballet themes proved sufficiently neutral to all patients except for one.

Problems with patients talking during recordings occurred, and although these parts of the tape were cut out manually afterwards, there were some difficulties determining when speech started and stopped. Coughing and head turning was easier to handle, because most of these episodes were cut out by the computer program automatically, and the pattern was more distinct. Also, other kinds of movements apart from TD (rabbit syndrome, tics, etc.) could course artefacts. Two patients had considerable head movements and were more restless during the last minute of the recordings, because of akathisia, indicating that the recording time in the darkened room was too long for some patients.

Internal reliability of DMA device

To evaluate the internal reliability of the apparatus, a test-retest of the DMA values was done using the backup tapes. The Pearson r coefficients were between 0.80 and 0.99 ($P < 0.005$; Table 2).

Table 2 Test-retest of the DMA device (internal reliability) using the backup tapes as a re-run for the RELAX and TASK mode. Pearson correlation coefficients (r) and two-tailed P-values

RELAX API interval (Hz)	r
1–3	0.94**
0–3	0.95**
3–6	0.85*
1-7	0.95**
TASK API interval (Hz)	
1–3	0.99**
1–3	0.99**
3–6	0.80*
1-7	0.97**

*$P < 0.005$
**$P < 0.0001$

Table 3 Concurrent validity. Correlations coefficients of API values (1–3 Hz; see text) and St. Hans Rating Scale (SHRS) dyskinesia scores (oral movements are jaw, tongue, lips and face; total TD is the sum of eight items, including extremities). Spearmann correlation of ranked data, two-tailed *P*-values; first and second examination

SHRS	RELAX	TASK	Mean
First examination ($n = 40$)			
Jaw movements (mean)	0.54**	0.71***	0.68***
Oral movements (total mean)	0.56**	0.73***	0.69***
Total TD (mean)	0.52**	0.70***	0.66***
Global TD	0.48*	0.70***	0.63***
Second examination ($n = 35$)			
Jaw movements (mean)	0.63**	0.56**	0.65***
Oral movements (total mean)	0.71***	0.59**	0.72***
Total TD (mean)	0.63***	0.52*	0.64***
Global TD	0.57**	0.54**	0.63***

*$P < 0.01$
**$P < 0.001$
***$P < 0.0001$

Table 4 Correlation coefficients of API values (1–3 Hz; see text) and AIMS score (oral items are jaw, tongue, lips and face; total is the sum of all TD items). Spearman correlation of ranked data, two-tailed *P*-values, first and second examination

	RELAX	TASK	Mean
First examination ($n = 40$)			
Oral movement score	0.32	0.61***	0.49*
Total TD score	0.34	0.61***	0.51**
Second examination ($n = 35$)			
Oral movement score	0.53*	0.54**	0.64***
Total TD score	0.53*	0.48*	0.60**

*$P < 0.01$
**$P < 0.001$
***$P < 0.0001$

In the 3–6 Hz band, the Pearson *r* was 0.85 for the session RELAX, and 0.80 for TASK. For all other frequency bands, the Pearson *r* coefficients were between 0.94 and 0.99 ($P < 0.0001$).

Concurrent validity

Dyskinesia

To test the validity of the DMA apparatus, API values of the 1–3 Hz band in the RELAX and TASK mode were correlated to the dyskinesia scores of the SHRS and the AIMS. As can be seen from Table 3, the API values showed a positive correlation with different SHRS items jaw movements and mean of all oral movements (jaw, lips), with Spearman correlation coefficients between 0.54 and 0.73 in both the first and the second examinations. The total SHRS dyskinesia values and the global scores also correlated relatively well with the API values (0.48–70). There were no consistent differences between the RELAX and TASK values. The mean value gave higher correlations (0.63–0.72). All corresponding *P*-values are shown in Table 3.

Table 5 Correlation coefficients of SHRS dyskinesia scores and Abnormal Involuntary Movement Scale (AIMS) scores. Spearmann correlations of ranked data, two-tailed *P*-values, first and second examination

	AIMS (oral items)	AIMS total mean
First examination ($n = 40$)		
SHRS (oral items active)	0.72**	0.70**
SHRS (oral items passive)	0.57*	0.62**
SHRS (total mean)	0.76**	0.81**
Second examination ($n = 35$)		
SHRS (oral items active)	0.71**	0.68**
SHRS (oral items passive)	0.64**	0.65**
SHRS (total mean)	0.70**	0.68**

*$P < 0.001$
**$P < 0.0001$

For the AIMS scores (oral scores and total scores) corresponding, although slightly lower, correlations, were found (Table 4).

The correlations between API values and SHRS and AIMS for the 23 patients who received unchanged medication during the two examinations (see Table 1) were similar to the aforementioned results (Spearman *r* coefficients 0.43–0.75; data not shown).

A comparison between SHRS and AIMS showed coefficients between 0.57 and 0.81 (Table 5).

Mild fluctuations in the intensity of TD occurred in most patients from the first to the second examination independent of the medication (Table 1). In some patients oral TD was reduced and in others increased, the mean intensity remaining unchanged (API values 45 at both exams and SHRS active oral score 2.6 and 2.5, respectively; see Table 1). No correlation was found between the changes in API values from the first to the second examination (API 1–2 m; see Table 1), and the corresponding changes in SHRS score (mean SHRS 1. to 2. examination; $r = 0.24$; $n = 26$; data not shown in Table 1).

Detection of parkinsonian tremor in the 4–7 Hz band

Spearman correlation coefficients for SHRS parkinsonism (total score) vs the DMA values (in the 4–7 Hz band of the RELAX and TASK phases and Mean of the two) were 0.39–0.53, lowest in the RELAX phase. At the first examination the TASK and Mean correlations were 0.50–0.51 and $P < 0.001$ (Table 6).

From the SHRS scores it was evident that a number of patients did not show any clinical parkinsonian signs. It was therefore decided to subdivide the patients into non-parkinsonian and parkinsonian patients and analyze the material with confidence intervals. The results are shown in Table 7. With a 95% level of confidence for SHRS total parkinsonian score > 5, we found confidence intervals

Table 6 Correlation coefficients of API values (4–7 Hz band) and SHRS scores, total of parkinsonism subscale (concurrent validity). Spearman correlation of ranked data, two-tailed *P*-values, first and second examination

	RELAX	TASK	Mean
First examination ($n = 40$)	0.39	0.51**	0.50**
Second examination ($n = 35$)	0.42	0.53*	0.53*

*$P < 0.01$
**$P < 0.001$

Table 7 The DMA device discrimination between patients with and without parkinsonism (an arbitrary SHRS total score of 5 used as cutoff) using the 4–7 Hz band and 95% confidence intervals

	Non-parkinsonian patients ($n = 26$)	Parkinsonian patients ($n = 14$)
First examination ($n = 40$)		
RELAX	16.0–18.5	18.8–23.3
Task	18.5–21.6	22.2–27.9
Mean	16.6–18.8	19.8–23.8
	Non-parkinsonian patients ($n = 25$)	Parkinsonian patients ($n = 10$)
Second examination ($n = 35$)		
RELAX	17.7–20.2	18.7–23.5
TASK	17.7–20.4	21.5–25.7
Mean	18.1–20.3	20.4–24.8

in the 4–7 Hz band for both RELAX, TASK and Mean in the first examination. In the second examination the interval matches in TASK and Mean, but not in RELAX (the interval is confident at the 90% level). This indicates that the new device detects parkinsonian tremor of the face that lies in the 4–7 Hz band.

Discussion

In this study a new device to quantify oral TD, digital movement analysis DMA, was evaluated. Even psychotic patients were able to participate and cooperate during both examinations. There were no problems with anxiety due to all of the equipment in the examination room. Thus, the acceptability of the method was high. The total recording time could probably be diminished from 5 to 3 min as suggested by Büchel et al. 1995, and this would make the device even more applicable in clinical drug trials.

The DMA device produced reliable results. Pearson correlation coefficients for the dyskinesia bands (1–3 and 0–3 Hz) and the overall 1–7 Hz band were very high, all above 0.94. In the parkinsonian band (3–6 Hz) correlation was slightly lower (0.80 and 0.85; $P < 0.005$).

There was a positive, although not very strong, correlation between the DMA measures and the clinical rating of oral TD (coefficients between 0.54 and 0.73). This result corresponds to or is slightly better than the results obtained in another study using AIMS and the Abbreviated Dyskinesia Rating Scale by Simpson et al. (1979) (Büchel et al. 1995). It should also be noted that the DMA values correlate well with the total and global TD scores, but it should be added that oral and extremity dyskinesias not always change in parallel (Greil et al. 1984). The lack of a correlation between the DMA and the ratings of the dyskinesia fluctuations over time in the present study further indicate that there is no complete correspondence between the instrumental and clinical evaluation. (For the sake of completeness it can be added that in this study no attempt was made to have the same level of TD during the two evaluations. Therefore, a 3-month interval was used and changes in the pharmacological treatment were allowed.)

This discrepancy between DMA values and rating scores may depend on either a higher sensitivity of the DMA device than of the clinical rating (as suggested by Büchel et al. 1995), or the inclusion of various non-TD movements in the DMA evaluation, although it was attempted to eliminate such movements from the final result. This question must be clarified in a future study, where the two examinations (DMA and clinical rating) are performed simultaneously, from exactly the same picture, and not in two successive time sequences. This is now possible due to a more advanced technique, allowing registration in full white light.

It was an interesting observation that the DMA device could detect perioral tremor as a parkinsonian sign, although the correlation between the API values and clinical parkinsonian score was only 0.39–0.53. Furthermore, the device significantly discriminated between patients with and without parkinsonism. This is a valuable addition to the use of this new TD evaluation device, because determination of parkinsonism is an obligatory part of any proper evaluation of dyskinesia.

In conclusion, DMA is a valuable instrumental method measuring jaw-lip dyskinesia. The device is easily applicable, has only minimal interference with the body parts measured (in contrast to other instrumental methods) and is accepted even by very psychotic patients. It makes a precise assessment of the movements, although further studies of validity are warranted to analyze the differences in DMA values and the clinical rating results found in this and another study (Büchel et al. 1995). Only the ultrasound technique may compete with the DMA, but there are a numer of drawbacks to this method including that the signal cannot be frequency analyzed, entailing that every movement within the area will be counted, whatever the nature (Khot and Wyatt 1991), and that high counts can be either related to high-frequency or high-amplitude movements. With the current device these problems are solved by the high-resolution frequency analysis. Thus, if the validity question can be satisfactorily resolved, the DMA appears to be the best instrumental method available for oral TD assessment and an excellent supplement to evaluation of TD by means of rating scales which are still indispensable in evaluating extrapyramidal syndromes.

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