Spiral Width Variability in Psychogenic Tremor

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OBJECTIVE

To determine whether psychogenic action tremors are marked by higher trial-to-trial width variability during a spiral drawing task, compared to organic tremor disorders such as essential tremor (ET) and dystonic tremor (DT).

BACKGROUND

Psychogenic tremor (PT), which accounts for up to 25% of all psychogenic movement disorders (PMD), is a challenging disorder to diagnose and treat. Arguably, a definitive diagnosis can only be made in retrospect, after symptomatic relief by psychotherapy. Still, improvements in our ability to diagnose PT are critical, as early diagnosis and treatment have been correlated with milder disability and better prognosis. To this end, much research has been geared towards furthering diagnostic criteria. Diagnosis is currently made through a combination of patient history, clinical exam, and electrophysiology, recognizing features that are inconsistent with organic movement disorders. Thus, typical indicators include: a sudden-onset of tremors, periods of remission, variability in amplitude and frequency, distractibility with mental concentration, suggestibility, entrainment, and amplitude increase with loading.

Because some of the classical features, such as tremor variability, can become less robust with disease duration, and methods of quantifying variability are generally limited to electrophysiology, which is not easily accessible to many clinicians, we were interested in whether spiral analysis could reveal additional, quantifiable features of variability in PT. Spiral drawing is a standard component of the neurological exam in which patients freely draw Archimedes spirals in a box. Spiral analysis, which utilizes a digitizing tablet and computer, was developed in our lab to quantify such drawings and has been found in the past decade to be a reliable measure that correlates well with other measures of upper limb motor control. Spiral width consistency has never been studied previously, although it has been observed that patients typically draw spirals that are consistent in shape and size from trial-to-trial, even despite the overlay of tremors. Further, variability is a major theme in PT. Thus, we were interested in whether PT patients exhibited a higher degree of spiral width variability compared to patients with essential tremor (ET) and dystonic tremor (DT), two organic tremor disorders that can manifest during action.

METHODS

STUDY SUBJECTS

A chart review of all patients and study subjects seen in our Clinical Motor Physiology Laboratory from 2003-2008 revealed 31 controls, and 22 PT, 20 ET, and 21 DT patients who met the following inclusion criteria: all subjects underwent spiral acquisition as part of their visit and had symptoms in at least one upper limb; controls had no known history of neurological disorders and were not on any medications; ET/DT patients had no other movement disorders; and PT patients had tremors that were inconsistent with classical movement disorders, and were found to be distractible (during a mental task) and variable (in frequency) by electrophysiology.

SPIRAL ACQUISITION

Subjects were seated comfortably in front of a digitizing tablet and instructed to start in the center of a 10 x 10 cm box on a sheet of white paper. Minimal instructions were given, but subjects were asked to neither anchor nor rotate their wrist so that drawing was standardized to the whole arm for all study subjects. A sample spiral was drawn by the examiner, and subjects were allowed to practice as much as they wanted. All subjects drew 10 spirals with each hand, starting with the right. Data consisting of position, pressure, and time were collected at a sampling rate of 100 Hz. Tablet resolution was 100 points/mm, with an accuracy of 0.127 mm, and output rate of 200 points/second, and 256 levels of measurable pressure.

SPIRAL ANALYSIS

Quantification of the handwritten spiral was based on "unraveling" the two-dimensional graphic, transforming the clinical presentation (shape, tremors, speed, etc…) into a data series of polar coordinates (radius, angle). This allowed further computational manipulations and the generation of numerous mathematical indices quantifying different parameters of upper limb motion during spiral drawing.

Our outcome measures were (1) the degree of severity (DOS), and (2) the 25%-75% width range. DOS is an overall measure of spiral execution that was mathematically modeled (and has been proven) to correlate with expert clinician ratings on the standard 0 (best) to 4 (worst) spiral rating scale. The 25%-75% range is a measure of the degree of maximum width variation from trial-to-trial in the more affected hand (as determined by the DOS). An average loop-to-loop width was determined for each of the 10 spirals, and the range from the 25% to 75% width values was taken. We chose to take the percentile ranges to be more stringent, and to allow for variation due to learning curve and chance errors.

Width itself was actually measured indirectly. The absolute width is problematic to calculate and can be impossible in many instances (e.g., when spiral loops cross, when there are tremors, or when the patient moves backwards in the spiral trajectory). Thus, we looked at the number of loops drawn (measured by the total angle traveled in radians) divided by the net radius, normalized to a value of 5 loops/10 cm (the value seen in healthy controls). Spirals with more than 5 loops in the 10 x 10 cm box will have a "width" value > 1 and are "tighter" than normal.

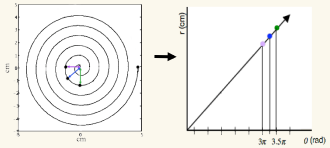
STATISTICAL ANALYSIS

Data were analyzed by the Mann-Whitney U test, with the level of significance set at $P < 0.017$, after Bonferroni correction.

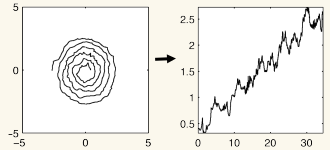
SPIRAL ANALYSIS

❖ CARTESIAN TO POLAR COORDINATES

Ideal Spiral (Computer-Generated)

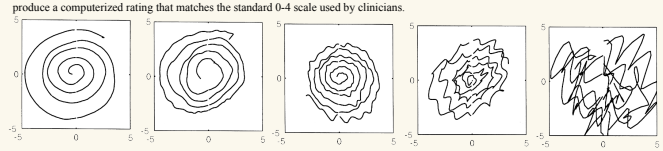


Sample Patient Spiral



❖ DEGREE OF SEVERITY (DOS)

DOS is an overall measure of spiral execution, taking into account various parameters such as speed and shape, and is mathematically modeled to produce a computerized rating that matches the standard 0-4 scale used by clinicians.

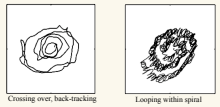


0 (Normal) **1 (Mild)** **2 (Moderate)** **3 (Severe)** **4 (Marked)**

❖ WIDTH CALCULATION

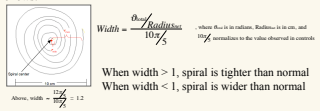
We define **spiral width** as the average spacing between consecutive loops in a given spiral.

But absolute width is not always feasible to measure, especially in patient-drawn spirals:



Crossing over, back-tracking Looping within spiral

Thus, we measure spiral width indirectly and normalize it, as follows:



$$Width = \frac{\theta_{total}}{Radius_{net}} \Big/ \frac{10\pi}{5}$$

where θ_{total} is in radians, $Radius_{net}$ is in cm, and $\frac{10\pi}{5}$ normalizes to the value observed in controls

When width > 1, spiral is tighter than normal
When width < 1, spiral is wider than normal

❖ PERCENTILE RANGE CALCULATION

Example: PT Patient (#15)

Widths for the 10 spirals of the more affected hand (left)

25th percentile of width: 1.022

75th percentile of width: 1.407

Range: 0.385

DEMOGRAPHICS: PT PATIENTS

Patient ID	Sex	Age	Tremor location	Sudden-onset	Amplitude Increase with Inertial Loading	Distractible	Variability in Tremor Frequency	Duration (months)**	Range**
1	Female	15	Hands	Yes	No	Yes	Yes	9	0.258
2	Male	16	Hand	Yes	Yes	Yes	Yes	12	0.109
3	Male	19	Whole body	Yes	No	Yes	Yes	48	0.313
4	Male	24	Forearm, hand	No	Yes	Yes	Yes	6	0.464
5	Male	24	Shoulders, arms, trunk, legs	Yes	No	Yes	Yes	4	0.523
6	Female	30	Whole body	Yes	Yes	Yes	Yes	7	0.242
7	Female	33	Whole body	Yes	No	Yes	Yes	24	0.249
8	Female	34	Head, jaw, tongue, hands, legs	No	Yes	Yes	Yes	72	0.573
9	Female	37	Head, arms, trunk	Yes	Yes	Yes	Yes	21	0.193
10	Male	41	Hand, leg	Yes	Yes	Yes	Yes	14	0.684
11	Female	43	Hand, leg	Yes	Yes	Yes	Yes	36	0.324
12	Female	43	Hands, whole body	Yes	No	Yes	Yes	72	0.169
13	Female	44	Arms	No	Yes	Yes	Yes	48	0.265
14	Female	45	Hands	Yes	Yes	Yes	Yes	10	0.506
15	Female	46	Hands	Yes	Yes	Yes	Yes	60	0.385
16	Female	47	Hands	Yes	Yes	Yes	Yes	48	0.315
17	Female	51	Hand	No	Yes	Yes	Yes	72	0.228
18	Male	51	Head, arms	Yes	No	Yes	Yes	24	0.134
19	Female	51	Hands, legs	Yes	Yes	Yes	Yes	18	0.195
20	Male	53	Hand	Yes	No	Yes	Yes	0.17	0.377
21	Female	66	Hands	Yes	Yes	Yes	Yes	18	0.275
22	Female	67	Finger	Yes	N/A	Yes	Yes	66	0.278

**There is no correlation between disorder duration and trial-to-trial width range (Spearman's rho = -0.161, $P = 0.473$), suggesting the validity of this approach for both early and longstanding PT.

DEMOGRAPHICS: ALL

Group	Age ± SD	Sex		Handedness	
		% Male	% Female	% Right	% Left
Control	45.1 ± 12.9	60%	40%	81%	19%
PT	42.9 ± 16.2	36%	64%	77%	23%
ET	64.6 ± 23.1	40%	60%	90%	10%
DT	49.5 ± 13.5	33%	67%	71%	29%

RESULTS

Group	Degree of Severity (DOS)		25%-75% Range	
	Median	*P* Value*	Median	*P* Value*
Control	0.822	0.00000	0.163	0.00005
PT	2.216	---	0.276	---
ET	2.413	0.30181	0.138	0.00013
DT	1.562	0.13197	0.172	0.00561

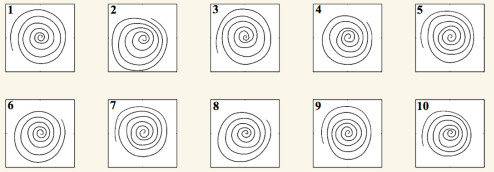
*P value for Mann-Whitney U test against PT group. Level of significance set at $P < 0.017$, after Bonferroni correction for multiple comparisons.

DOS distinguishes PT patients from healthy controls, but not ET or DT patients.

The 25%-75% range, however, is significantly higher in PT patients than in healthy controls or patients with ET or DT.

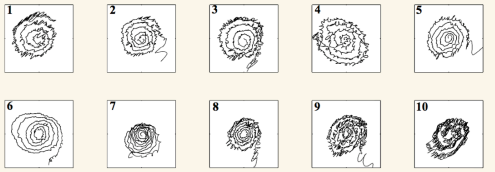
CONTROL

DOS: 0.561 / Width Range: 0.163



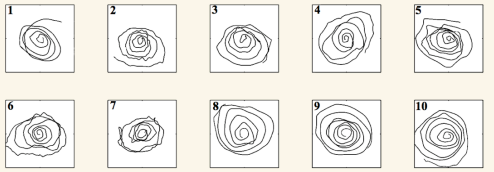
PSYCHOGENIC TREMOR

DOS: 3.734 Width Range: 0.490



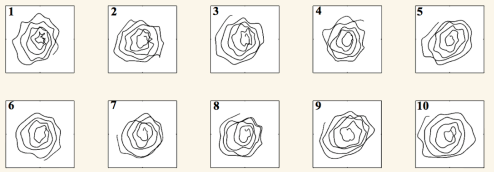
DYSTONIC TREMOR

DOS: 3.189 / Width Range: 0.199



ESSENTIAL TREMOR

DOS: 3.122 / Width Range: 0.147



DISCUSSION

- PT patients draw spirals that are score poorly on the standard 0-4 spiral rating scale; but this does not distinguish PT patients from patients with other organic disorders, such as ET or DT.
- However, PT patients show greater variation in the average spiral width across ten spiral drawing trials, suggesting that PT patients were less capable of maintaining the same deviations from trial to trial.
- This is a new and less intuitive measure of variability that might be valuable, particularly in cases of long-standing PT (in which tremor variability is less robust) or instances in which electrophysiology is not feasible and a method of objectively quantifying variability is desired.
- Future directions include looking at variability through the ordered trials (where sequence matters), and determining whether spiral width variability is valid across different disease durations (whether it becomes less robust, like tremor variability). Here, we did not find a correlation between disease duration and range, but this is not entirely valid as we screened for patients who show tremor variability.

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