

Inhibition and synchronisation of tremor induced by a muscle twitch

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SUMMARY The effects of a muscle twitch on the tremor of the extensor indicis muscle and of the tibial anterior muscle have been recorded in 14 patients with essential tremor and in 10 patients with Parkinson's disease. The muscle twitch evoked by the electrical stimulation of the motor nerve inhibits the tremor and synchronises it. The mean duration of the inhibition is 92.1 ± 6.8 ms for essential tremor and 183.0 ± 16.8 ms for Parkinsonian tremor. This inhibitory phase lasts longer when the muscle twitch is induced during the second half of the Parkinsonian tremor cycle. The effects of voluntary contraction and of unloading suggest that inhibition and resetting of the tremor can be attributed to the autogenic mechanism induced by Ib fibres discharges. The presence of a rhythmic inhibition in the cycle of Parkinsonian tremor accounts for the longer duration of the inhibitory phase. In practice, these techniques aid the diagnosis of tremor in these two conditions, for example they assist the identification of low frequency essential tremor and of postural tremor in Parkinson's disease.

A muscle twitch elicited by electrical stimulation of a nerve provokes a halt in the rhythmic activity of Parkinsonian tremor lasting 200-250 ms. The tremor EMG bursts which reappear after this inactive phase change in frequency for a short period.^{1,2} The duration of this inactive phase is much longer than the classical silent period³⁻⁵ induced by a twitch upon a muscle in voluntary contraction. Thus, Parkinsonian tremor can be suppressed and reset by peripheral stimulation. Recently, Teravainen *et al*⁶ have also shown that short external perturbations in limb position change the phase of Parkinsonian resting tremor.

The present study investigates this phenomenon both in essential tremor and Parkinsonian tremor, to see if it is specific to the latter, and investigates the pathophysiological mechanisms involved.

Method

1 Patients Ten patients with Parkinsonian tremor and 14 patients with essential tremor

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were studied. Relevant clinical features are summarised in tables 1 and 2. Tremor was the main symptom of the disease in five cases in the Parkinsonian group. The ages of the patients ranged from 46 to 69 years. In the group of patients with essential tremor, a family history was found in five cases. The duration of the tremor ranged from three months to 17 years and the ages of the subjects from 27 to 79 years.

Table 1 Clinical data and related EMG findings in patients with essential tremor

Patient	Sex	Age (yr)	Illness duration (yr)	Tremor frequency Hz	Duration of IPIMT
1	M	44	17	6-7	80
2	F	26	14	10-12	80
3	F	70	15	10-12	80
4	M	49	31	5-6	100
5	F	57	0-41	10-12	80
6	M	74	5	10	100
7	M	44	10	10-12	90
8	M	30	2	10	120
9	M	71	0-50	8-12	80
10	F	38	0-25	9	80
11	F	71	5	5-6	100
12	M	53	3	8	100
13	M	51	2	10	100
14	M	79	3	5-6	100
Mean		54.07	7.72	9.0	92.1
SD				2.3	12.5
SE				0.6	3.4

IPIMT: inactive phase induced by a muscle twitch.

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Table 2 Clinical data and related EMG findings in patients with Parkinsonian tremor

Patient	Sex	Age (yr)	Illness duration (yr)	Exam	Medication	Tremor frequency Hz	Duration of IPIMT
1	F	68	0-41	R, AK	Amantadine	5-6	180
2	F	69	4	R, AK	Artane L-Dopa	4-5	160
3	M	46	5	0	Artane L-Dopa	4-5	170
4	M	54	4	0	Amantadine L-Dopa	4-5	200
5	F	66	10	0	DCI L-Dopa-DCI	5-6	150
6	M	52	10	R, AK	Artane L-Dopa, DCI	5-6	170
7	M	59	5	0	Amantadine L-Dopa	6-7	160
8	M	69	22	0	β -blocker	5	220
9	F	59	8	AK	L-Dopa	6-7	200
10	M	52	7	R, AK	L-Dopa	5-6	220
					Amantadine		
Mean		59.4	7.5			5.4	183.0
SD						0.7	25.4
SF						0.2	8.4

R: rigidity. AK: akinesia. IPIMT: inactive phase induced by a muscle twitch.

The patients gave informed consent to all the investigations and procedures carried out.

2 Electrophysiological methods The analysis of the muscle twitch effect on tremor was mainly performed on the extensor indicis muscle (EI). In some cases, Parkinsonian tremor was studied both in extensor indicis and in tibialis anterior.

The subject was seated in a chair, the upper-limb semi-flexed, the forearm relaxed on the table for study of extensor indicis tremor. The leg was extended, the knee slightly flexed for study of tibialis anterior tremor.

A muscle twitch was induced by electrical stimulation. Extensor indicis twitch was evoked by stimulation of the radial nerve at the arm and tibialis anterior twitch was evoked by stimulation of the peroneal nerve at the knee. The stimulus was a square-wave impulse of 1.0 ms duration at a frequency of 1.0 Hz. Stimulation was triggered at varying times in the tremor cycle.

The classical silent period was studied by examining the unloading reaction of the extensor indicis muscle. The patient was sitting comfortably in a chair, with the hand, the wrist and the elbow fixed on a support. The index finger was splinted so that only the metacarpophalangeal joint could move, to which a weight was attached by a cord running over a pulley. The patient was asked to keep the finger horizontal. The unloading reaction was obtained by cutting the cord.

The electromyographic responses (EMG) were recorded by surface electrodes. Tremor activity

was obtained by a single plane accelerometer (Grass SPA 1). During the experiments, EMG signals and tracings of tremor were continuously displayed by an oscilloscope and a loud-speaker. Selected sequences were stored on an analog tape recorded (Philips Minilog 4) for subsequent photographic and computer analysis.

Results

1 Muscle twitch effects on Parkinsonian tremor

An example of the effects of a muscle twitch taken from a single subject on Parkinsonian tremor is illustrated in fig 1. The histogram of intervals of 100 cycles of this tremor presents a mean interval of 204.2 ± 30.0 ms, corresponding to a frequency of 5.4 ± 0.7 Hz. A supra-maximal stimulation of the radial nerve which induced a muscle twitch of the extensor indicis, had a double effect on the Parkinsonian tremor rhythm recorded in that same muscle:

a The radial nerve stimulation synchronised the bursting pattern of the extensor indicis. The EMG activity was increased in the first burst as well as in the following one or two bursts. An oscillation of the period of the rhythm was observed along with the oscillation of the amplitude of the tremor. The mean duration of the oscillation of the period of the rhythm was 600 to 800 ms.

b The radial nerve stimulation induced an EMG silence which lasted from 160 to 260 ms (table 2). The mean duration recorded from 10 Parkinsonian patients was 183.0 ± 16.8 ms (mean

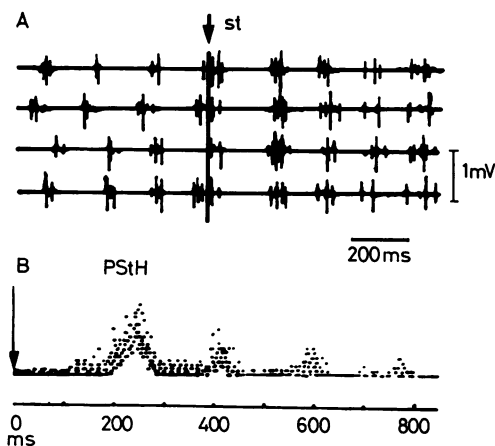


Fig 1 Effects of muscle twitch induced by the stimulation of radial nerve (St) on Parkinsonian tremor recorded in extensor indicis. A—typical EMG recordings of Parkinsonian tremor and changes evoked by a muscle twitch. Note the resetting of tremor activity and the inactive (inhibitory) phase duration. B—post-stimulus histogram (PStH) of tremor activity. Calibrations: 1 mV and 200 ms.

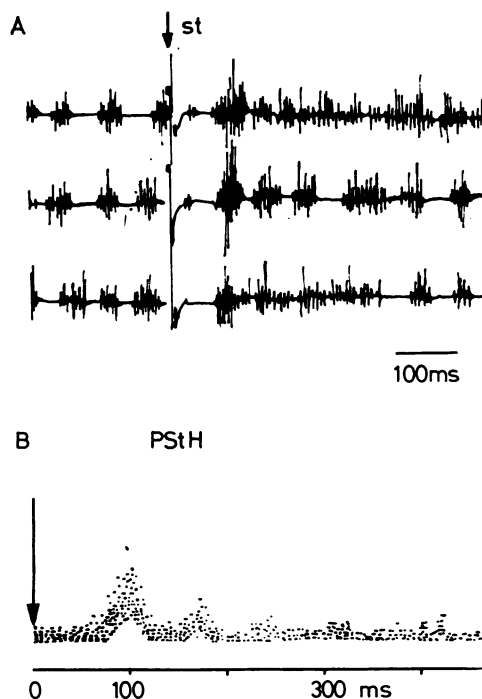


Fig 2 Effects of muscle twitch on essential tremor. EMG recordings (A) and post-stimulus histogram (PStH) as in fig 1. Note the resetting of tremor activity and the shorter inactive (inhibitory) phase duration. Calibrations: 0.5 mV and 100 ms.

± 2 standard errors). When the suppression was not complete, that is radial nerve stimulation was not supra-maximal and induced only a weak extensor indicis muscle twitch, a burst of tremor of small amplitude could be recorded during the inactive period.

The same pattern of results was recorded in the fibralis anterior muscle on stimulating the peroneal nerve in five of the same Parkinsonian patients.

2 Muscle twitch effects on essential tremor

Essential tremor is commonly observed in the upper limb. Muscle twitch effects were studied in extensor indicis on stimulating the radial nerve. The frequency of tremor recorded in extensor indicis muscle ranged from 5 to 6 Hz in four cases and from eight to 12 cases. The same pattern of results was obtained in the 14 patients (table 1).

The ability of muscle twitch to synchronise bursts in extensor indicis and to suppress the EMG activity is shown in fig 2. The superimposed vertical lines of stimulation artefact between the records show that tremor, which initially was bursting out of phase was now synchronised.

The post-stimulating histogram shows that, as in Parkinsonian tremor synchronisation

lasts about 3 or 4 tremor cycles; mean duration of the inactivation induced by muscle twitch was 92.1 ± 6.8 ms in the 14 patients.

3 Modulation of the effects induced by a muscle twitch

(a) *Inactive phase and tremor cycle* The duration of inhibition induced by the muscle twitch at four different points of the tremor cycle is shown in fig 3. In the Parkinsonian patients, the tremor cycle lasted 200 ms and burst duration 80 ms. When the muscle twitch was presented during the burst, the occurrence of the next burst was slightly delayed. When it was presented later in the tremor cycle (150 ms and 180 ms after the onset of the burst), the next burst was significantly more delayed. The longest inactive phase occurred with the muscle twitch near the end of the tremor cycle.

On the other hand, the tremor cycle was more variable in essential tremor and its duration was 91.0 ± 9.0 ms. The inactive phase evoked

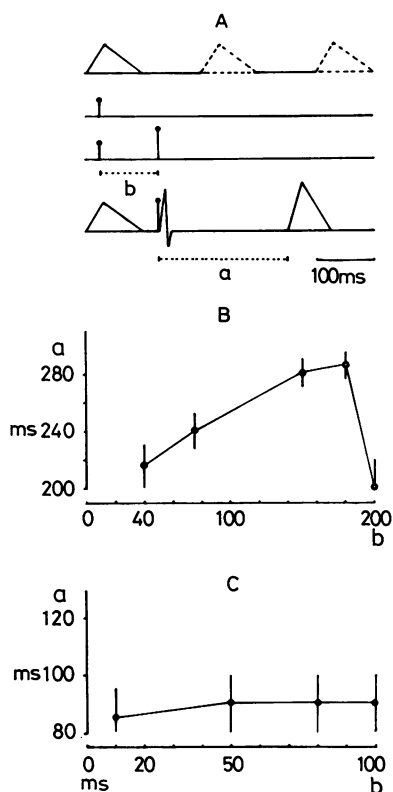


Fig 3 Changes in the inactive phase duration evoked by a muscle twitch as a function of its place in the tremor cycle. *A*. Schematic illustration of the method used to calculate the coordinates of the curves *B* for Parkinsonian tremor and *C* for essential tremor. Ordinates (*a*): inhibition-duration measured from the stimulation to the onset of the first tremor burst. Mean ± 2 SEM ($N=10$) not represented. Abscissa (*b*): Latency of the stimulation triggered from the pre-stimulus burst. Note the increase of the inhibition duration in Parkinsonian tremor only when the muscle-twitch was in the later phases of tremor cycle.

by the muscle twitch did not vary as a function of its timing in the tremor cycle (fig 3 C).

(b) *Effect of isometric voluntary contraction* which produces a state of tonic central facilitation of motoneurons. The data recorded from a Parkinsonian patient are illustrated in fig 4. The mean frequency did not change. The inactive phase induced by a muscle twitch, however, is clearly shorter. Its mean duration was 210 ± 10 ms before and 110 ± 30 ms during isometric con-

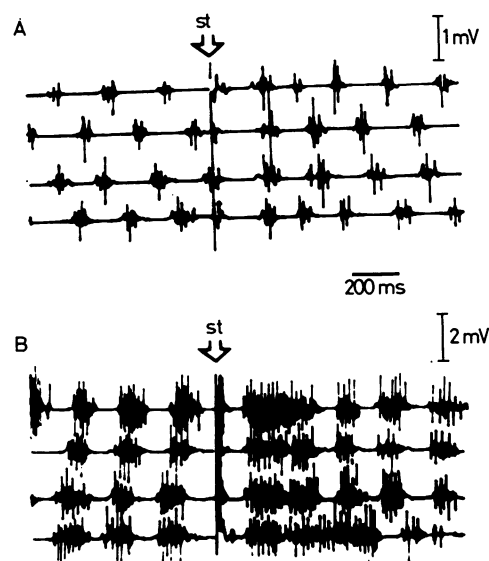


Fig 4 Effects of a muscle twitch on Parkinsonian tremor during tonic voluntary contraction. Note the shorter inactive phase duration during tonic voluntary contraction.

traction. In essential tremor, the inactive phase in the same conditions lasted as long as the classical silent period, ie 90 ± 20 ms.

(c) *Unloading test* Data shown in fig 5 refer to the effects of a spindle pause on Parkinsonian tremor and essential tremor. Parkinsonian tremor did not change in frequency when the muscle in tonic contraction was unloaded suddenly. In essential tremor, unloading provoked the usual silent period of 80–100 ms duration (fig 5 B).

Discussion

1 Mechanism of inhibiting induced by a muscle twitch

The techniques of unit recording from muscle nerves in man have corroborated the experimental data from animals⁶ concerning the discharges induced by a muscle twitch. A spindle pause occurs during the contraction⁷⁻¹¹ as does activity of Ib afferents.^{8,12} The pause of the Ia discharges accounts for the silent period of the “unloading” during an isometric contraction.^{3,13,14} Several phenomena are involved in the mechanism of the muscle twitch-induced silent period described by Hoffmann,¹⁵ among them the spindle pause and autogenic inhibition.

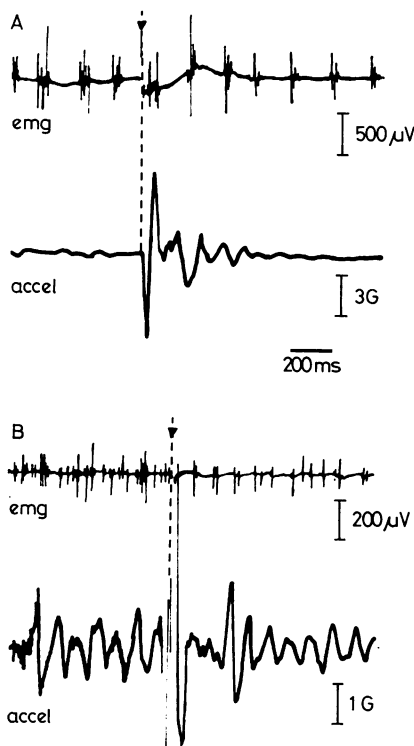


Fig 5 Effects of unloading reflex on Parkinsonian tremor (A) and essential tremor (B). Note that there is no change in frequency in Parkinsonian tremor and a normal silent period in essential tremor.

Bursts of Ia discharges of two kinds appear when recording spindle activity during Parkinsonian tremor¹⁶: those synchronous of the tremor bursts and others occurring during the silent period. This Ia activity is different from the continuous Ia discharge observed in an isometric contraction⁹⁻¹¹ and may minimise the effect of a spindle pause induced by introduction of a muscle twitch in tremor.

The temporary suppression of Parkinsonian tremor noted in this study can be explained by the inhibitory effect of the muscle twitch inducing Ib discharges. The selective excitation of Ia fibres by vibration¹ and by isometric voluntary contraction does not suppress but shortens tremor duration. The difference observed between Parkinsonian and essential tremor is another matter, and may be due to the difference in the mechanisms of the two kinds of tremor.²

According to oscillator terminology¹⁷⁻¹⁹ Parkin-

sonian tremor is more "isochronous" than essential tremor. Inhibition produced by the muscle twitch may reset a bursting oscillator in two different ways. In essential tremor phase delay is fixed and does not exceed the tremor cycle, so has the same value as a usual silent period. On the other hand, in Parkinsonian tremor the phase delay is a function of the phase of the burst cycle in which the twitch is introduced. In the later phases of the burst cycle, phase delay is relatively long when compared to the burst cycle length. Its duration may be the sum of the inhibition induced by muscle twitch and that inherent to the Parkinsonian tremor mechanism.

2 Segmentary excitability during tremor.

The recording of spindle discharges during Parkinsonian tremor showed that the EMG rhythmic bursts preceded the spindle activity so it can be concluded that the myotatic stretch reflex loop does not take part in the initiation of each rhythmic burst. However, spindle discharge may induce an excitatory effect on the last part of the rhythmic burst and a reciprocal inhibitory effect on antagonist motoneurons.¹⁶ These data are in favour of a central origin of the tremor rhythm, but do not exclude the role of peripheral afferents in the clinical expression of tremor.

When testing motoneurone excitability by the amplitude of the H reflex, it appears to decrease during the silent period and to increase just before the next tremor burst.^{1,2} In the present work the excitability of motoneurons has been tested by inhibitory impulses presented by a muscle twitch. It is known that the normal duration of a silent period evoked by a muscle twitch is 80-120 ms.^{5,20} In essential tremor, the mean duration of inhibition is 92.1 ± 6.8 ms (fig 2 and table 1). In Parkinsonian tremor, the duration of the inhibition lasts longer (183.0 ± 16.8) and it is even more prolonged if the muscle twitch is triggered during the silent period of the tremor cycle (fig 3). These results suggest that different physiopathological mechanisms are involved in these two kinds of tremor.

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