利用交互抑制反射和牽張反射對肌肉痙攣作定量分析
Quantification of the Spasticity by Reflex Torque and Reciprocal Inhibition

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一、中文摘要

肌肉痙攣是中樞神經系統疾病最常見的後遺症之一。它是由於牽張反射異常而產生的一種隨牽張速度增加而增強肌肉張力的現象。到目前为止並沒有一種理想的工具可以定量它，因此我們發展一套利用測量牽張反射來定量肌肉痙攣的線上量測系統。這套系統使用的方式是對上臂做不同速度的等速牽張來得到我們要的結果。另一方面，我們也採用交互抑制反射的方式來評估肌肉痙攣在神經電生理上的變化。並將反得到的結果和臨床上的半定量評量（modified Ashworth Scale, MAS）作比較。結果顯示我們這套線上量測系統及交互抑制反射得到的結果都和臨床評量呈現明顯的正相關。

二、研究方法

We studied in upper limbs of 21 patients (14 men, 7 women) with unilateral post stroke spasticity. The mean age was 61 years (range = 42 - 77 years). Only the patients of a single-side supratentorial stroke with spasticity were included. However, they must had no other concomitant central nerve system disorders or cognitive impairment, and were cooperative. The peripheral nerve and muscle function, which were verified by nerve conduction velocity and EMG tests, had to be normal. Patients with joint deformity or other pathologies on tested joints were also excluded. Eleven healthy volunteers (5 men, 6 women) were recruited as controls. Informed consent was obtained for participation in the study.

Clinical assessment of spastic hypertonia was made by flexing and extending the upper limb before the objective studies. Spastic hypertonia was graded on an ordinal scale from 0 to 5 based on modified...
Ashworth scale (MAS). A same examiner to avoid inter-examiner variation did all the clinical assessments. There were six patients with grade 1 spasticity, five with grade 2, seven with grade 3, and three with grade 4. No patient with grade 5 spasticity was recruited, as considered with the safety.

The spasticity measurement system consists of three subsystems: mechanical structure, measurement, and control subsystem. Subjects were tested at supine position with face up while the elbow was positioned at approximately 110° elbow flexion and 90° shoulder abduction. Then, the upper limb was stretched toward the ground, i.e. in a vertical-stretching mode. The motor would extend the elbow for 75° at a constant angular velocity. (Fig. 1A) According to the experience, 80 deg/sec was chosen as the stretch velocity. Nine tests with the stretch velocity in 80 deg/sec and four tests in 5 deg/sec, which were measured and averaged as the baseline torque, in a randomly chosen sequence were performed for each subject.

The measured torque in Fig. 1B is a combination of gravity, stretch reflex, and acceleration/deceleration inertial torque. We may divide the torque curve into five regions. The torque values before stretching (region I) and after termination (region V) are attributed to the gravity of upper limb and attached manipulators as well as the negligible passive elastic torque due to stretch of muscle. The pulse-like reactive torque (regions II and IV) is due to the inertia and vibration of manipulator and elbow. It is noted that the reaction force toward the ground positively acts on the torque sensor and vice versa. The dynamic torque, i.e., the region III, is mainly attributed to the measured spasticity and gravity but has minimum inertia and vibration reactive torque.

Assumed that at a slow velocity, the stretch reflex would not be induced and the inertial torque is negligible. Thus, the torque measured during a slow stretch velocity, 5 deg/sec chosen in this research, is defined as a baseline torque. The baseline torque is used to subtract the gravity and elastic effect during the test. The averaged difference between the measured torque at the speed of 80 deg/sec and the baseline torque in the dynamic range (region III) is called as averaged speed-dependent reflex torque (ASRT, Fig 1C). The ASRT is used herein to quantify the spasticity.

In the reciprocal inhibition study, subjects were awake and lying supine with arms resting parallel to the trunk. Disc electrodes are used to record the surface electromyogram (EMG) from the bellies of the flexor carpi radialis (FCR) and the extensor digitorum communis (EDC). The surface EMG was amplified with a band-pass filter of 100 Hz to 3k Hz by Nicolet Viking IV. The impedance between the cathode and anode was kept < 5k Ohm during the studies. Throughout the study, we also made sure the arms were fully relaxed and the amplitude of H-reflexes did not change significantly as our previously study.

Constant-current stimulators (Nicolet model S403) were used to delivered the electrical stimuli at a frequency of one every 5 s (0.2 Hz) and 1 ms in duration. The "test stimuli" were delivered to the median nerve at the antecubital fossa and their intensity was adjusted to be approximated 70 % of the maximal H-reflex from the FCR. The "condition stimuli" were delivered to the radial nerve at the spiral groove and their intensity was set to be 90 % of motor threshold.

Time intervals between test and conditioning stimulus were -1, -0.5, 0, 0.5, 1, 2, 3, 5, 10, 20, 30, 50, 70, 100, 200, and 500 ms. Positive time interval indicated that the test stimuli were delivered after the conditioning stimuli, whereas negative one indicated the opposite. Ten "test H-reflexes" (recorded with test stimuli only) and 10 "conditioned H-reflexes" (recorded with test stimuli plus conditioning stimuli) were averaged at each delay. The averaged peak-to-peak amplitude of conditioned H-reflex was expressed as a percentage of the
averaged peak-to-peak amplitude of test H-reflex for each delay.

三、結果

In normal subjects, the torque measured in the high velocity (80 deg/sec) was closed to, but not overlapped with, the baseline measured in the velocity of 5 deg/sec. In patient groups, the curves of measured torque were different in patients with distinct severity of spasticity. The changes of torque were more significant in patients with higher score graded on modified Ashworth scale (MAS). (Fig. 2) The Spearman’s rank correlation coefficient was used to analyze the correlation between the clinical assessment and the measured ASRT. It showed significant positive relationship between the ranks of these two variables. (Rho=0.836, p<0.001)

The result of reciprocal inhibition test disclosed diminished inhibition in the second and third inhibitory phases. ANOVA analysis indicated significant difference between patients with spasticity for delays of 20 ms (p< 0.05; f= 11.812), 70 ms (p< 0.05; f=6.238), and 200 ms (p< 0.05; f= 6.123). The change in the first inhibitory phases was not significant. When dividing patient data into their respective groups of muscle tone, we also noted that there was a tendency to show the more severe in spasticity the more diminishing in the second and the third inhibitory phases. (Fig. 3) But the correlation between the score of MAS and the changes in the reciprocal inhibition was not statistically significant.

四、討論

1. The value of ASRT is greater in patients having more marked spasticity. The Spearman’s rank correlation coefficient also shows significant linear correlation between the ASRT and the clinical scale.
2. On the other hand, the value of ASRT measured in control groups is small and the curve closes to but not equals to the baseline, suggesting that the muscle tone caused by the stretch reflex is indeed presented in normal subjects. The only difference between normal subjects and spastic patients is the abnormal increase of stretch reflex in patients with spastic hypertonia. The increased amount is proportional to the severity of the spasticity.
3. The result of the reciprocal inhibition shows diminished inhibition in the second and the third inhibitory phases. It indicates that spasticity is not only caused by the pathologic changes in the polysynaptic long-latency reflex pathway, but also the abnormality of the presynaptic inhibition at spinal cord.
4. The changes of the inhibitory phases are proportional to the severity of spasticity in some way. The limited case number may be the reason why the difference is not statistically significant. It may need more effort on it.

五、結論

We may conclude that the normalized relative torque deviation, ASRT, is a useful tool to quantify the spasticity. On the other hand, the result of reciprocal inhibition test indicates that the spasticity is caused by not only the problem of the long-loop reflex, but also the change in the presynaptic inhibition. It also deserves further study on the value of quantifying the spasticity by the reciprocal inhibition test.

六、參考文獻


A: On-line spasticity measurement system
B: The measured torque
C: The Averaged Stretch Reflex Torque (ASRT)

\[ ASRT = \frac{\text{Area}}{\text{Duration (P1-P2)}} \]

\[ ASRT = \frac{1}{P_2-P_1} \int_{P_1}^{P_2} T_w(\theta) - T_S(\theta) \, d\theta \]

Fig. 1

Fig. 2 The measured curve of torque in patients with different severity of spasticity.
A: MAS 1; B: MAS 2; C: MAS 3; D: MAS 4
Fig. 3 Results of reciprocal inhibition tests. Comparing the result of normal controls and patients with different severity of spasticity
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