Japanese Journal of Comprehensive Rehabilitation Science (2015)

Original Article

Factors influencing therapeutic effectiveness of phenol motor point block on using ankle plantar flexion torque

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ABSTRACT

Maeda H, Sonoda S, Tomita Y, Mizuno S, Takeda K, Miyasaka H, Tanino G, Orand A, Ohno K. Factors influencing the therapeutic effectiveness of phenol motor point block on using ankle plantar flexion torque. Jpn J Compr Rehabil Sci 2015; 6: 118–123.

Objective: The therapeutic effectiveness of phenol motor point block in patients with spasticity of the lower extremity was assessed by measuring ankle plantar flexion torque. Patient factors influencing therapeutic effectiveness were evaluated.

Methods: Twelve patients with spasticity of the lower extremity after cerebrovascular disorders were enrolled in this study. Plantar flexion torques at 5°/s or 90°/s under passive ankle dorsiflexion were measured before and after treatment with phenol motor block in flexor muscles of the lower leg. Patient factors influencing therapeutic effectiveness were evaluated before and after treatment using torque changes as an indicator of therapeutic effectiveness.

Results: Therapeutic effectiveness showed a significantly negative correlation with plantar flexion torques at 5°/s before treatment ($\rho = -0.741$, $p = 0.006$) and with the time from onset ($\rho = -0.680$, $p = 0.015$). A significantly positive correlation between therapeutic effectiveness and presence of self-exercise ($\rho = 0.661$, $p = 0.019$) was observed.

Conclusion: Patients who were less affected by immobilization including those with small plantar flexion torque at 5°/s or those who engaged in self-exercise are expected to achieve large therapeutic effects with regard to phenol motor point block against spasticity of the lower extremity.

Key words: spasticity, plantar flexion torque, quantification, phenol motor point block, immobility

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Accepted: September 23, 2015

No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

Introduction

Spasticity, defined as a velocity-dependent increase in tonic stretch reflexes [1], disturbs activities of daily living (ADL) in patients with cerebrovascular disorders. Phenol motor point block (phenol block) and botulinum toxin are often used to treat spasticity. It is important to identify the candidate symptoms for the abovementioned treatments and to determine their effectiveness; however, its validation is not enough. This is partially because the choice of methods for evaluating muscle tone is limited.

General clinical examinations including the evaluations of motion, pain caused by spasticity, clonus and tendon reflex, and subjective rating scales such as Modified Tardieu Scale (MTS) [2–4] and Modified Ashworth Scale (MAS) [5, 6] are used in the clinical evaluation of exaggerated muscle tone. Although these scales are easy to use in clinical practice, their reliability is low [6–9].

Plantar flexion torque under passive ankle dorsiflexion has been employed for the quantitative evaluation of muscle tone [10–17]. However, in situations in which this type of device was not commercially available, few studies used plantar flexion torque to evaluate therapeutic effectiveness against exaggerated muscle tone, i.e., using botulinum toxin treatments to the elbow [18, 19], ankle [20], or knee [21, 22] after stroke or in case of cerebral palsy.

In this study, we evaluated the factors influencing the therapeutic effectiveness of phenol block in patients with cerebrovascular disorders by measuring plantar flexion torque as an indicator of resistance torque.

Methods

1. Subjects

Twelve patients who developed spasticity of the lower extremity after cerebrovascular disorders and who were inpatients or outpatients in our hospital between April 2013 and April 2015 were enrolled in the study. Phenol block to flexor muscles of their lower leg, including gastrocnemius, was administered to all patients by their primary physician. Nine subjects were males and three were females. Mean age was 57.6 ± 9.2 (median, 58) years. Eleven subjects were inpatients and the other was an outpatient. There were seven cases of cerebral infarction and five cases of cerebral bleeding. The average time from onset to intervention was 361.6 ± 849.0 (median, 73.5) days. This study was approved by the Local Ethics Committee of Nanakuri Sanatorium, Fujita Health University (approval number 97). Informed consent was obtained from all patients.

2. Torque measurement device

We used the stiffness measurement system developed by Tomita et al. as a measuring device [23]. This device comprises a double-upright ankle foot orthosis (DU-AFO), an electric motor, and a control unit, which facilitates the maintenance of a constant angular velocity in passive ankle dorsiflexion (Figure 1). Motor power is converted to passive ankle dorsiflexion power via a rack and pinion. The dorsiflexion angle was measured using a potentiometer mounted on the ankle joint axis. Plantar flexion torque was measured using strain gauges attached to the flange on the DU-AFO to which a motor was affixed.

3. Phenol block and protocol of torque measurement

Measurements were performed before and after phenol block. Phenol block was performed with 5% phenol after locating the most suitable injection site by isolated electrode injection needles.

A pre-injection evaluation was performed on the day before or on the day of the injection; post-injection evaluation was performed within 2 days after the injection. The patients sat either on a chair with a back support or in a wheelchair with their back reclined at 30°, with their lower extremity positioned on a specially designed support to keep the knee flexion at 60°. The ankle was passively dorsiflexed from 20° of plantar flexion to 10° at 5°/s (slow speed) and 90°/s (high speed). Plantar flexion torque at a dorsiflexion of 10° was used as an evaluation index. Indices of torques were calculated at slow speed before (T10SlowPre) and after treatment (T10SlowPost) and at high speed before (T10FastPre) and after treatment (T10FastPost). Torque differences between the fast and slow speeds (T10Fast−T10Slow) before (T10SubPre) and after (T10SubPost) treatment were calculated. Furthermore, pre-post differences (T10SubPre − T10SubPost) were calculated and referred to as T10SubDiff (Table 1).

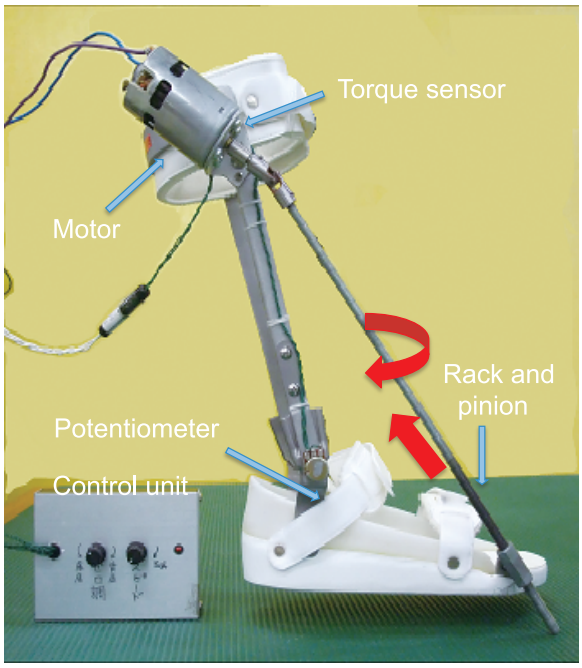

Figure 1. Ankle-joint stiffness measurement device. The device developed by Tomita et al. [23] was used for ankle stiffness measurement.

Table 1. List of abbreviations.

SIAS-mLE toral	The sum of motor function items of lower extremity in the Stroke Impairment Assessment Set
FIM-m	The sum of the Functional Independence Measure motor items
FIM-gait	The Functional Independence Measure walk item
T10Slow	Plantar flexion torque at a dorsiflexion of 10° with 5°/s under passive dorsiflexion
T10Fast	Plantar flexion torque at a dorsiflexion of 10° with 90°/s under passive dorsiflexion
T10SlowPre	T10Slow before phenol block
T10FastPre	T10Fast before phenol block
T10SlowPost	T10Slow after phenol block
T10FastPost	T10Fast after phenol block
T10SubPre	T10Fast Pre−T10SlowPre
T10SubPost	T10Fast Post−T10SlowPost
T10SubDiff	T10Sub Pre−T10subPost

4. Other assessments

Assessments made before measuring pre-treatment torques included the Functional Independence Measure (FIM), MAS, motor function items of lower extremity in the Stroke Impairment Assessment Set (SIAS-mLE), severity of ankle clonus (0: none, 1: unsustained, and 2: sustained), AFO (0: unused and 1: used), self-exercise other than rehabilitation with therapists (0: never and 1: doing). Self-exercise was rated as "doing" if patients routinely performed stand-up or gait exercise regardless of the existence of a helper (family, nurses, care worker, and so on). The sum of the FIM motor items (FIM-m) and the FIM walk item (FIM-gait) in the FIM and the sum of the SIAS-mLE (SIAS-mLE total) and foot-pat test score in the SIAS were used in the statistical analyses. The demographic data of the patients are shown in Table 2.

5. Statistical analyses

T10SubDiff was used as an indicator of therapeutic effectiveness. Spearman's rank correlation coefficients between T10SubDiff and each assessment item (age, time from onset to intervention, T10FastPre, T10SlowPre, T10SubPre, SIAS-foot pat, SIAS-mLE total, MAS, clonus, FIM-m, FIM-gait, use of AFO, and self-exercise) were calculated.

The top six patients with higher T10SubDiff value were defined as the "large-effect group" and the others were defined as the "small-effect group" in this study. The relationship between each group and each assessment item was analyzed using the Wilcoxon rank sum test or chi-square test. The statistical software JMP® 11 (SAS Institute Inc., Cary, NC, USA) was used and the significance level was set at $p < 0.05$.

Results

Spearman's rank correlation coefficients between T10SubDiff, used as an indicator of therapeutic effectiveness, and patients' factors are shown in Table 3. Time from onset (ρ= −0.680, p = 0.015), T10SlowPre (ρ= 0.741, p = 0.006), and self-exercise (ρ= 0.661, p= 0.019) were significantly correlated. Other measurements were not significantly correlated.

The cut-off value between the large- and small-effect groups was T10SubDiff of 5 Nm. A scattergram, in which the large- and small-effect groups were differentiated according to color, of plantar flexion

Table 3. Spearman's rank correlation coefficients between an indicator of therapeutic effectiveness (T10SubDiff) and each assessment item.

	T10SubDiff	
	ρ	p
Age	0.445	0.147
Time from onset	−0.680	0.015*
T10FastPre	−0.490	0.106
T10SlowPre	−0.741	0.006**
T10SubPre	0.406	0.191
SIAS foot-pat	0.037	0.910
SIAS-mLE total	0.021	0.948
MAS	0.039	0.903
Clonus	0.256	0.421
FIM-m	0.000	1.000
FIM-gait	0.201	0.532
AFO	0.307	0.332
Self-exercise	0.661	0.019*

*: $p < 0.05$ **: $p < 0.01$

Table 2. The demographic data of the patients.

Subject	Age (years)	Sex	Time from onset (days)	Disease	SIAS-mLE	MAS [0−4]	Clonus	FIM-m [13−91]	FIM-gait [1−7]	AFO [0 or 1]	Self-exercise [0 or 1]
S1	69	Male	65	Bleeding	4/4/3	1+	1	65	5	1	1
S2	64	Female	60	Infarction	2/2/1	2	2	56	3	1	1
S3	59	Female	81	Infarction	3/3/1	2	2	78	6	1	1
S4	40	Male	75	Bleeding	2/2/0	2	2	51	4	1	0
S5	48	Female	72	Bleeding	1/1/1	2	1	50	5	1	1
S6	51	Male	3,030	Infarction	4/3/3	1+	2	69	2	0	0
S7	57	Male	475	Bleeding	4/4/3	2	1	88	6	0	0
S8	67	Male	72	Infarction	3/3/2	2	2	66	5	0	0
S9	71	Male	54	Infarction	2/2/0	3	0	34	3	1	0
S10	51	Male	218	Bleeding	3/2/0	3	2	67	5	1	0
S11	60	Male	59	Infarction	4/3/1	2	2	77	5	1	1
S12	54	Male	78	Infarction	1/1/0	1+	2	27	2	1	0

Note: SIAS-mLE: hip [0−5]/knee [0−5]/ankle [0−5]; AFO 0: unused and 1: used; Self-exercise 0: never and 1: doing.

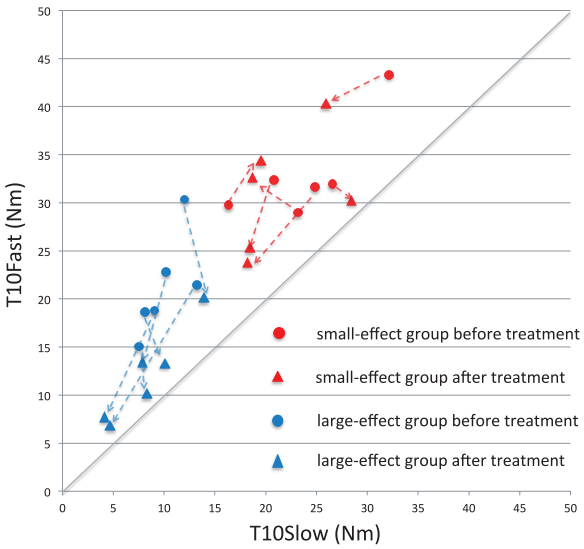

Figure 2. Plantar flexion torque before and after treatment.
The horizontal axis represents plantar flexion torque at dorsiflexion of 10° with 5°/s and the vertical axis represents plantar flexion torque with 90°/s under passive ankle dorsiflexion. Arrows indicate torque changes in the same patients before and after treatment.

torques before and after treatment is shown in Figure 2. T10SlowPre and T10FastPre in the large-effect group were significantly lower than those in the small-effect group (p = 0.005 and p = 0.013, respectively; Table 4a). This tendency was prominent in T10SlowPre. On comparing the two groups, no items other than T10SlowPre and T10FastPre showed significant differences (Table 4a). The chi-square test revealed significant differences in the SIAS-foot pat (p = 0.005) and self-exercise (p = 0.001) by groups (Table 4b). A cross table of these two items is shown in Table 4c.

Discussion

This study showed that the therapeutic effectiveness of the phenol block was related to the plantar flexion torque at the speed of 5°/s (T10SlowPre) and to the presence or absence of self-exercise.

In this study, using the plantar flexion torque during passive dorsiflexion enabled a quantitative evaluation of the effectiveness of phenol block. The plantar flexion torque at a slow speed of passive movement (T10Slow in this study) denotes the length-dependent (elastic) component, whereas the plantar flexion torque at a high speed of passive movement (T10Fast in this study) indicates the sum of the elastic and velocity-dependent (viscosity and neural) components [23, 24]. Because spasticity is defined as a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes with exaggerated tendon jerks resulting from hyperexcitability of the

Table 4a. Comparison between the two groups divided by an indicator of therapeutic effectiveness (T10SubDiff).

(Wilcoxon rank sum test)

	Small-effect group	Large-effect group	p
Age	52.5	62	0.229
Time from onset	148	68.5	0.128
T10FastPre	31.76	20.11	0.013*
T10SlowPre	24.01	9.62	0.005**
T10SubPre	8.66	10.67	0.471
SIAS-mLE total	4.5	7.5	0.573
FIM-m	59	65.5	0.689

*: $p < 0.05$ **: $p < 0.01$

Table 4b. Chi-square test of an indicator of therapeutic effectiveness (T10SubDiff).

	χ^2 value	p
SIAS foot-pat	12.816	0.005**
MAS	4.441	0.109
Clonus	1.726	0.422
FIM-gait	6.086	0.193
AFO	0.451	0.502
Self-exercise	10.894	0.001**

*: $p < 0.05$ **: $p < 0.01$

Table 4c. Cross tables between an indicator of therapeutic effectiveness (T10SubDiff) and SIAS foot-pat or self-exercise.

		SIAS foot-pat			
		0	1	2	3
T10SubDiff	Small-effect group	4	0	0	2
	Large-effect group	0	4	1	1

		Self-exercise	
		never	doing
T10SubDiff	Small-effect group	6	0
	Large-effect group	1	5

Note: Only cross tables of items for which the chi-square test revealed significant differences by groups are shown.

stretch reflex as a component of the upper motor neuron syndrome [1], it can be classified by a velocity-dependent component, i.e., the subtraction of T10Fast from T10Slow (T10Sub). Thus, we employed T10SubDiff as an indicator of therapeutic effectiveness.

Evaluation of muscle tone, such as by using MAS, is influenced not only by the increase in the velocity-dependent neural component but also by the change in a non-neural component because of the change in the muscle fiber or the connective tissue [25, 26]. Because immobilization increases the viscoelasticity of the muscle and connective tissue [27−30], immobilization of triceps surae enhances the non-neural component during passive ankle dorsiflexion.

The presence or absence of self-exercise was correlated with the therapeutic effectiveness of the phenol block and may represent the degree of viscoelasticity increase because of immobilization. This hypothesis is supported by the negative correlation of T10Slow that shows an elastic component [23, 24] and the effectiveness of phenol block treatment. T10Fast also showed a negative correlation with the effectiveness of phenol block treatment, which may be the result of the elastic component included in T10Fast.

The negative correlation found between the time from onset to intervention and the effectiveness of phenol block may be because of the inclusion of patients with an extremely long time to intervention. Immobilization and increase of viscoelasticity may play a role in this relationship.

Based on the discussion above, an increase in the plantar flexion torque at passive dorsiflexion does not necessarily guarantee a favorable result of phenol block. In addition to the increased plantar flexion torque, patients who are less affected by immobilization, such as those with small T10Slow or those engaged in self-exercise, may be good candidates for phenol block.

Elevated T10Fast after treatment was observed in 2 patients (S7 and S10 in Table 2) out of 12 patients. Although it is difficult to determine the reason, exaggerated muscle tone by pain or nociceptive stimulus may cause this phenomenon. S7 was an outpatient and a temporal restriction easily induced pain by passive dorsiflexion just after treatment. Since the pain complaint of S10 was massive even before phenol block, the data of S10 was susceptible to the effect of the pain induced by the treatment.

Finally, we should mention two problems remaining to be solved. Since our measurement system in this study was made for the purpose of research, it is difficult to evaluate T10SlowPre that relates to the therapeutic effectiveness of phenol block in clinical situations. Hand-Held Dynamometry (HHD) was used to measure the joint resistance during passive ankle dorsiflexion in patients with cerebral palsy [31, 32]; the estimation of T10Slow using HHD is a solution. However, we must solve problems such as the reliability of HHD data in relation to the examiner's muscle power or the way of fixing the device [33−35], as well as the linearity between the data of HHD and T10Slow.

In this study, T10Sub that shows a velocity-dependent component at passive dorsiflexion includes viscosity, a non-neural velocity-dependent component [25, 26]. Recently, a method of separating the resistance torque at passive movement into neural and non-neural components in the elbow, wrist, and ankle joint has been reported [14, 16, 17, 36]. Our future studies will aim to determine the effectiveness of phenol block by isolating the neural component from plantar flexion torque.

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