The Clinical Efficacy of Botulinum Toxin Injections to the Upper Lumbrical Muscles for Clenched Fist Deformity in Chronic Stroke Patients

Kayako NITTA, Takashi KASAHARA, Hiroshi TANAKA, Hidenori KANKE, Yuji KOYAMA, Minoru TOYOKURA and Yoshihisa MASAKADO

Department of Rehabilitation Medicine, Tokai University School of Medicine

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Objective: Post-stroke hemiplegic patients with a spastic clenched fist deformity that was caused by upper motor neuron syndrome often have problems with hygiene and nursing. Botulinum toxin-A (BTX-A) had been given for treatment of such patients to relieve spasticity by targeting finger joint muscles, such as the flexor digitorum superficialis and flexor digitorum profundus. However, some of these patients do not have satisfactory outcomes. Therefore, we aimed to examine the clinical efficacy and outcome of BTX-A treatment that targeted the upper lumbrical muscles (ULM) in patients with spastic clenched fist deformity caused by stoke.

Methods: Chronic stroke patients with spastic clenched fist deformity who received BTX-A treatment were evaluated retrospectively. We obtained data from medical records before and at 4 weeks after BTX-A injection to the ULM. The clinical data and outcome measures analyzed included range of motion, the Modified Ashworth Scale, the numeric graphic rating scale for pain, and 2 items from the disability assessment scale (ease of cleaning palm and trimming nail).

Results: Wilcoxon signed rank test showed that BTX-A treatment significantly improved all measures.

Conclusion: BTX-A therapy to the ULM provided satisfactory outcomes in improving spastic clenched fist.

Key words: botulinum toxin, spasticity, upper limb, upper lumbrical muscles, clenched fist

INTRODUCTION

A spastic clenched fist deformity caused by upper motor neuron syndrome in hemiplegic patients often leads to problems with hygiene and nursing for both patients and caregivers. Examples of such problems are difficulties maintaining hygiene of the palms and fingers and cutting fingernails, as well as pain and infection caused by the fingernails inadvertently pricking the palm. Moreover, a clenched fist often affects the activities of daily living and quality of life of the patients.

To improve a spastic clenched fist, we have been using botulinum toxin-A (BTX-A) therapy, which reduces muscle contraction, and have been recommended as spasticity treatment. BTX-A reversibly blocks peripheral cholinergic transmission at the neuromuscular junction, resulting in reduced muscle contraction. Clinical effect occurs gradually over 4–7 days, occasionally longer, and usually can last for 3–4 months [1]. Patients often receive injections repeatedly after the effects has worn off.

For the treatment for the clenched fist, so far, the flexor digitorum superficialis (FDS) and the flexor digitorum profundus (FDP) have been the main targeted muscles, but we encountered some patients whose clenched fist did not improve. The FDS and the FDP mainly flex the proximal interphalangeal joint and the distal interphalangeal joint, respectively; both the FDS and FDP are supplementary flexors of the metacarpophalangeal joint (MPj) [2]. In some cases with clenched fist due to increasing MPj spasticity, we sometimes experienced successful improvement after administration of BTX-A injection to the upper lumbrical muscles (ULM), which are the main flexors of the MPj. One review article referred to the possibility of improving clenched fist by injecting BTX-A into the ULM, when MPj spasticity seems to be the main problem, but the article does not cite exact numerical data or reports referenced by the original articles [3]. Although few reports on BTX-A injection to the ULM are available, these were only case reports [4–6]. Our purpose is to examine and evaluate the effect of BTX-A injection to the ULM statistically.

PATIENTS AND METHODS

Subjects

This was a retrospective study in which medical records from April 2013 to March 2015 were reviewed. The data and evaluation of chronic stroke patients who attended our hospital and received BTX-A injection to the ULM were collected. Inclusion criteria were as follows: clenched fist deformities caused by upper limb spasticity from stroke that was documented by computed tomography or magnetic resonance imaging scan; fingers and wrist in flexed position, especially the

Kayako NITTA, Department of Rehabilitation Medicine, Tokai University School of Medicine, 143 Shimokasuya, Isehara, Kanagawa 259-1193, Japan
Tel: +81-463-93-1121 Fax: +81-95-8248 E-mail: ka_ya_arata@yahoo.co.jp

Table 1 Modified Ashworth Scale

Grade	Description
0	no increase in muscle tone
1	slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion when the affected part(s) is moved in flexion or extension
1+	slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM
2	more marked increase in muscle tone through most of the ROM, but affected part(s) easily moved
3	considerable increase in muscle tone, passive movement difficult
4	affected part(s) rigid in flexsion or extension

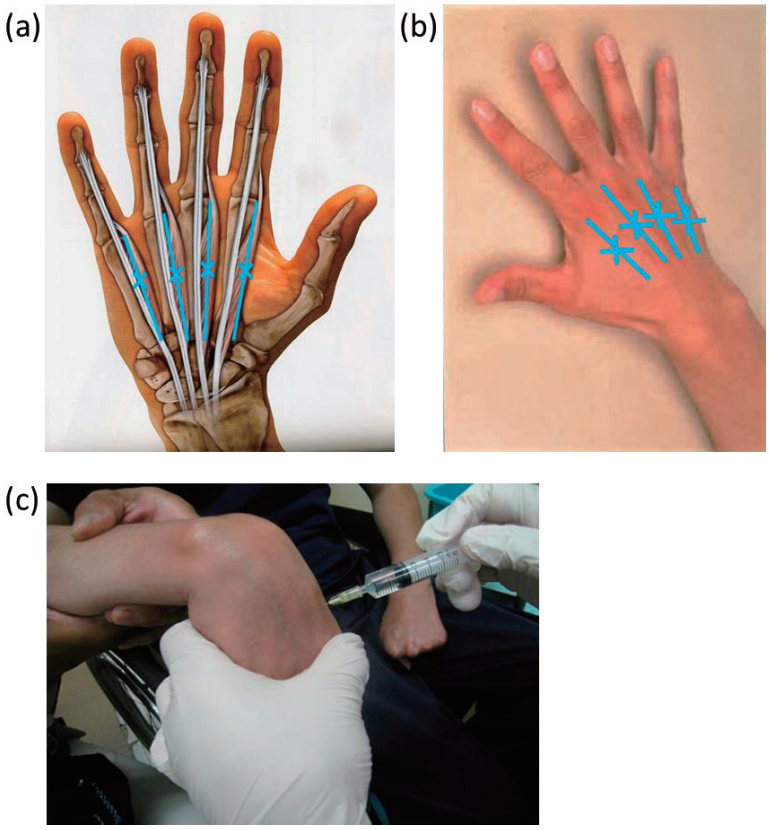

Fig. 1 Injection by dorsal approach
Upper lumbrical muscle (ULM)s were identified visually and by palpation without using electrical stimulation or sonography.
(a)(b) Anatomic site of ULM
(c) Injection in ULM by dorsal approach

MPj, with a tone grade of at least 2 on the Modified Ashworth Scale (MAS, Table 1) [7]; at least 6 months from stroke onset; and at least 4 months from the last BTX-A treatment. This study was approved by the Institutional Review Board for Clinical Research, Tokai University (reference number: 17R301). The investigation conformed with the principles outlined in the Declaration of Helsinki [8].

Injection procedure

Botulinum toxin-A (BOTOX® for injection, GlaxoSmithKline K.K., Tokyo, Japan) was diluted in 0.9% sodium chloride solution to make a concentration of 2.5 units/0.1 ml for injection. Fig. 1 shows our method for BTX-A injection. We used dorsal approach [9]. Each of the 1st to the 4th ULM was identified visually and by palpation. After identifying the radial edge of the metacarpal bone, an intramuscular injection was performed 1–2 mm away from the edge of the bone at a depth of 1–2 cm, depending on the thickness of the hand. Using a 5ml-syringe with a 23G-needle, 0.4–0.5 ml of BTX-A solution was injected into each muscle [4]. No electrical stimulation or ultrasound was used. No other extra treatment or rehabilitation program was given before and after BTX-A injection.

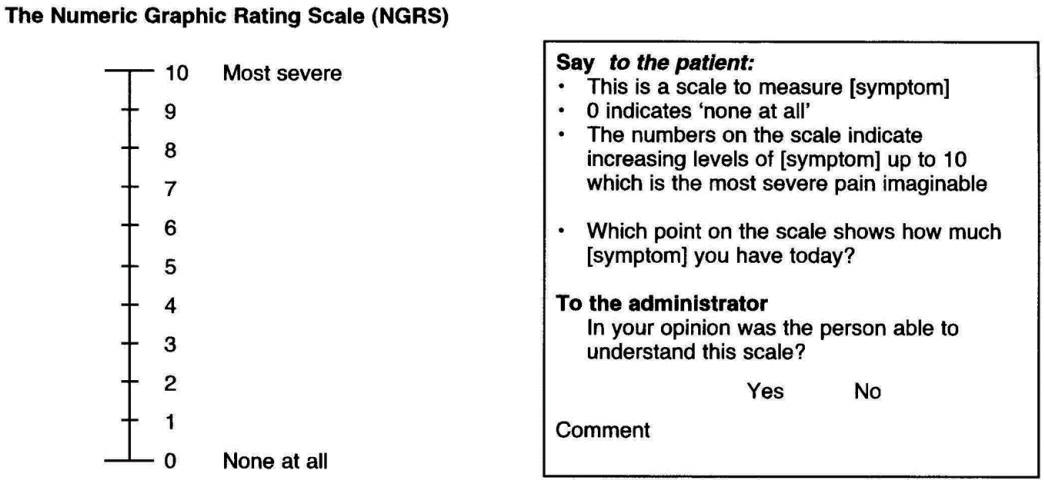

Fig. 2 The numeric graphic rating scale for pain (NGRSp)
We measure [pain] for [symptom]. Pain is caused by finger extension.

(a)

Hygiene	The rater assessed the extent of maceration, ulceration, and/or palmar infection; palm and hand cleanliness; ease of cleanliness; ease of nail trimming; and the degree of interference caused by hygiene-related in the patient's daily life.

(b)

0	no disability
1	mild disability (noticeable but does not interfere significantly with normal activities)
2	moderate disability (normal activities require increased effort and/or assistance)
3	severe disability (normal activities limited)

Fig. 3 Disability Assessment Scale (partial quote)
(a) Assessment of the hygiene domain was performed according to the following guidelines (partially quoted).
(b) The raters interviewed each patient to determine the extent of functional impairment for patient hygiene, dressing, limb position, and pain according to the following scale.

Evaluation

The clinical data and outcome measures analyzed were range of motion (ROM), which was measured on the most flexed finger using a goniometer for the MPj angle in a flexed wrist; MAS of the MPj flexor in a flexed wrist, which was measured on the most flexed finger; the numeric graphic rating scale [1] for pain (NGRSp, Fig. 2), when all the fingers were extended at the same time; and 2 items from the Disability Assessment Scale (DAS, Fig. 3) [10], including ease of cleaning the palm and hand and trimming the nail. For MAS, "1+" was analyzed as a score of 1.5 [11]. The DAS for functional impairment that is commonly seen in patients with post-stroke upper limb spasticity was assessed by physiatrists who interviewed each patient about hygiene-related disability (i.e., ease of nail trimming and ease of palm and hand cleanliness), according to the following scale shown in Fig. 3. These parameters were evaluated before and at 4 weeks after BTX-A treatment.

Statistical analysis

Statistical analyses were carried out using the Statistical Package for Social Sciences version 25 (SPSS Inc., Chicago, IL, USA). Data were presented as mean ± standard deviation (SD). Wilcoxon signed-rank test was used to compare paired data. P values of < 0.05 were considered to indicate statistical significance.

RESULTS

Table 2 presents the clinical features of the study population, which included patients with spastic clenched fist deformity from chronic cerebral hemorrhage (n = 7, 5 men and 2 women); chronic cerebral infarction (n = 1, man); and subarachnoid hemorrhage (n = 1, woman). Their age range was 55–87 years old, 0.5–15 years had passed from onset, and all but patient number 9 received BTX-A treatment in other muscles at the same time. As shown in Table 3, BTX-A treatment improved all evaluation scales in most patients except for patient number 8, who showed less improvement with worsening in NGRSp. As reported in Table 4, every item showed significant improvements after BTX-A treatment.

DISCUSSION

According to the results of our study, BTX-A therapy to the ULM improved the ROM, MAS, pain, and hygiene problems caused by a spastic clenched fist. In some patients, clenched fist deformity is caused by increased spasticity of the ULM. In a patient with MAS 4 clenched fist, the deformity is mainly from a contracture, which cannot be moved passively, and in general, cannot be relieved by BTX-A therapy. In this

Table 2 Clinical features of patients
Patients had clenched fist deformity (i.e., MPj flexed in wrist flexed position), which was caused by the stroke. Time since the last BTX-A treatment was at least 4 months. Injection was administered to the other muscles at the same time.

Patient number	1	2	3	4	5	6	7	8	9
Age (years)	75	80	55	66	87	75	82	56	65
Sex (M/F)	M	M	F	M	M	M	F	F	M
Time from onset (years)	13	12	3	13	15	11	3	7	0.5
Stroke type	CI	CH	CH	CH	CH	CH	SAH	CH	CH
Other muscles*	PM BB FCR FCU FDS FPL	BB FCR FCU FDS	BB FCR FCU FDS	Br FCR FCU FPL	PM FCR FCU FDS AP	FCR FCU	BB FCR FPL	PM BB	none

*other muscles for which BTX-A treatment was administered at the same time
CH: cerebral hemorrhage, CI: cerebral infarction, SAH: subarachnoid hemorrhage, PM: pectoralis major, BB: biceps brachii, Br: brachialis, FCR: flexor carpi radialis, FCU: flexor carpi ulnaris, FDS: flexor digitorum superficialis, FPL: flexor pollicis longus, EPB: extensor pollicis brevis, AP: adductor pollicis, BTX-A: botulinum toxin-A

Table 3 Evaluation of the patient before and after BTX-A treatment
All the evaluation scales showed improvement or no change, except for the worsening degree in the NGRSp in patient number 8.

Patient number		1	2	3	4	5	6	7	8	9
ROM (degree)	before	-65	-45	-10	-30	-30	-45	-30	-80	-80
	after	-40	-35	0	0	5	-20	0	-60	-45
MAS	before	4	2	2	3	2	3	3	4	3
	after	1.5	1.5	1	1	1.5	1	1	3	2
NGRSp	before	7	10	4	8	5	10	5	2	6
	after	1	5	1.5	1	0	1	2	4	3
Trimming nail	before	4	2	3	3	3	3	3	0	3
	after	2	1	2	1	1	1	1	0	1
Cleaning palm	before	2	2	3	3	2	3	2	2	3
	after	1	1	2	1	1	1	1	1	1

BTX-A: botulinum toxin-A, ROM: range of motion, MAS: Modified Ashworth Scale, NGRSp: the numeric graphic rating scale for pain

Table 4 Statistical analysis of the evaluations
P values of < 0.05 were considered to indicate statistical significance at Wilcoxon signed-rank test.

	Before BTX-A (mean ± SD)	**After BTX-A (mean ± SD)**	**P**
ROM	-46.1 ± 24.3	-21.7 ± 24.1	< 0.01
MAS	2.9 ± 0.8	1.5 ± 0.7	< 0.01
NGRSp	6.3 ± 2.7	2.1 ± 1.6	< 0.05
trimming nail	2.7 ± 1.1	1.1 ± 0.6	< 0.01
cleaning palm	2.4 ± 0.5	1.1 ± 0.3	< 0.01

ROM: range of motion, MAS: Modified Ashworth Scale, NGRSp: the numeric graphic rating scale for pain, BTX-A: botulinum toxin-A, SD: Standard deviation

Table 5 Characteristics of the two approaches for upper lumbrical muscles

	Advantages	Disadvantages
Palmar injection approach	Easy to identify on the superficial side if the fingers are extended enough	Difficult to give injection to fingers that are hardly flexed
Dorsal injection approach	Good finger and hand positioning for administration of injection Proper cleanliness before injection	Often difficult to detect and approach accurately because of the depth

study, we demonstrated a case with MAS 4 clenched fist that was improved by BTX-A treatment. In such MAS 4 clenched fist cases from contracture spasticity, BTX-A therapy could be worth trying.

Although ROM after BTX-A treatment improved in all the patients, the degree of improvement in each patient varied. Spasticity can result in anatomic distortion, such as a spastic clenched fist, which may decrease the accuracy of injections [12]. Moreover, with our method, we cannot ascertain that the BTX-A solution was injected into the target muscles. Therefore, the smaller effect of BTX-A therapy might have been brought about by inappropriate injection.

Unexpectedly, in patient number 8, the NGRSp scale increased after BTX-A therapy. We supposed that this was due to technical errors in BTX-A injection. In that MAS4 case, the patient's fingers were strongly flexed by severe spasticity, which rendered the MPj immobile and made it difficult to extend the finger adequately before BTX-A therapy. With proper technique, the NGRSp in this patient might have been higher. There might be other factors to explain this problem, but the number of patients was not large enough to analyze this issue.

In some patients with post-stroke clenched fist that cannot be relieved sufficiently by BTX-A injection to the FDS or FDP, multiple target muscles, such as intrinsic muscles, should be considered. Among these other muscles, the ULM is considered to be one of the primary muscles affected in a clenched fist. The interossei palmares (IOP) and interossei dorsales (IOD) are supplementary flexors of the MPj, although the IOP mainly adducts the MPj [2], which could worsen a clench fist. For the flexors of the MPj of the 4th finger, the abductor digiti minimi and opponens digiti minimi are auxiliary muscles, whereas the flexor digiti minimi brevis is a main muscle [2]; however, it is unlikely that these muscles are mainly affected in a clenched fist.

With our method, the BTX-A could have been injected to the IOD or IOP. One study reported that even if the injection to the ULM was performed accurately, it can still possibly influence the adjacent muscles, such as the IOD and IOP [13]. We consider that it is less necessary to identify ULM from IOD or IOP strictly, for the aim of this treatment is to reduce the spasticity of MPj flexor muscles, and IOD and IOP auxiliary flexes MPj [2]. Our procedure could be said quite appropriate for practical treatment.

There are 2 procedures for injecting the ULM. One is approaching from the dorsal side of the hand (dorsal injection approach), and the other is from the palmar side (palmar injection approach) [9]. Their characteristics are shown in Table 5. In this study, we chose the dorsal injection approach, because it was difficult to approach from the palm in clenched fist deformities. Although the ULM is easier to identify on the palmar aspect, the dorsal injection approach may be more feasible, given the hand positioning and the ability to properly clean before the injection [12].

The present study had several limitations. First, it is uncontrolled retrospective before-after study, with a small sample size. In before-after study, it is difficult to exclude the subjectivity of the observers. Second, evaluating scales include subjective information. “Pain” itself is subjective evaluation. DAS includes subjective information. And it is generally agreed that MAS has limited reliability and reproducibility [14]. In fact, MAS is one of the semi-quantitative evaluation, but usually employed to assess the clinical effectiveness of BTX-A treatment, and still widely used [15, 16]. Despite this, the study provided useful insight in evaluating effectiveness of BTX-A injection to ULM in terms of functional improvement. Finally, in this research, all the patients except for patient number 9 received BTX-A injection to other muscles in addition to the ULM. We planned the inclusion criteria so that the data would not be affected by the other muscles as much possible, but the influence of the other muscles may not be excluded.

In order to further validate our findings on the value of injecting the ULM in chronic stroke patients, future studies on larger samples and the use of a crossover design are required. It may be worth evaluating and comparing cases of injection to the ULM alone, to the ULM and FDS or FDP, and to the FDS, FDP, and ULM. Moreover, the use of electrical stimulation and ultrasound may enable more accurate evaluations.

CONCLUSION

BTX-A treatment of the ULM by dorsal injection improves clenched fist deformities. We suggest BTX-A treatment for MAS 4 clenched fist patients, as it may be effective in some cases.

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