The Efficacy of Ultrasound-guided Selective Botulinum Toxin Type A Therapy for Finger Spasticity Following Stroke: A Case Report

Toshiaki FURUKAWA[*1], Yuka KURIHARA[*2] and Yoshihisa MASAKADO[*2]

[*1]*Department of Rehabilitation Medicine, Tokai University Hachioji Hospital*
[*2]*Department of Rehabilitation Medicine, Tokai University School of Medicine*

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A 64-year-old man had spasticity of digits 3 and 4 of the right hand for 22 years following a stroke. Activities of daily living (ADL) were impaired due to the disuse of the right arm. The flexor digitorum superficialis and flexor digitorum profundus muscles of digits 3 and 4 of the patient's right forearm were identified using ultrasound guidance, and botulinum toxin type A was selectively injected into those sites. Furthermore, following the injections, occupational therapy was performed for the right arm and fingers, and spasticity was assessed after 2 weeks and at 1, 2, 3, 4, and 5 months. The patient showed improvement in all the evaluations (the Modified Ashworth Scale, Disability Assessment Scale, functional independence measure, active range of motion angle, and movement of holding a cup), and function was maintained throughout the evaluation period. Performing botulinum toxin type A injection under ultrasound guidance to selectively identify the flexor digitorum superficialis and flexor digitorum profundus muscles involved in finger spasticity helped restore finger functioning and improve ADL.

Key words: finger spasticity, ultrasound-guided injection, flexor digitorum superficialis muscle, flexor digitorum profundus muscle, selective botulinum toxin type A therapy

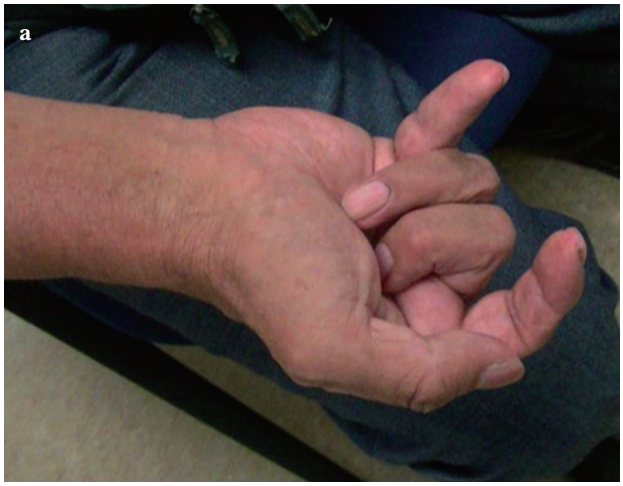
INTRODUCTION

In the rehabilitation of upper limb dysfunction following stroke, botulinum toxin type A (BoNT-A) therapy is an effective means of treatment for severe spasticity. This therapy is designed to improve hand hygiene and reduce the amount of care needed for dressing and everyday necessities as well as nursing care (passive function). Furthermore, it is also an effective means of restoring motor function (active function), such as reaching for, grasping, and releasing an object. The safety and therapeutic effects of BoNT-A therapy for spasticity of the upper limbs as well as different injection techniques have previously been reported [1–8]. In particular, it has been reported that electromyographic guidance and electrical stimulation in addition to ultrasound guidance are superior in terms of accuracy and effectiveness when compared with manual needle placement using surface anatomical landmarks [9]. In the treatment of flexion spasticity of the fingers, the targets are the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) muscles in digits 2–5. However, the extent of spasticity often varies between the digits. To yield effective treatment outcomes and achieve rehabilitation, it is important to accurately identify muscles and selectively administer treatment while taking into account the injection dose. In such instances, ultrasound-guided injection is an effective technique in terms of safety, accuracy, and efficacy. Here, we report our experience of a case in which the muscles were accurately identified using ultrasound guidance and effective treatment was selectively administered.

CASE PRESENTATION

The subject was a 64-year-old man who developed a cerebral infarction of the left putamen on January 24, 1991. Right hemiplegia was classified as Brunnstrom stage IV for the upper limb, IV–V for the digits, and IV for the lower limb. The Brunnstrom stages is a short and easily administered measure for assessing motor function. The Brunnstrom stages contains items: the upper limb (arm, hand), and the lower limb , all of which are rated on a 6-level Likert-type scale (level I to VI). Higher levels represent better motor function. The subject's score for functional independence measure (FIM) was 112 points. The FIM is an 18-item of physical, psychological and social function. Contains 18 items composed of: 13 motor tasks, 5 cognitive tasks (considered basic activities of daily living). Scores range from 18 (lowest) to 126 (highest) indicating level of function. The tool is used to assess a patient's level of disability as well as change in patient status in response to rehabilitation or medical intervention. He could extend digits 1, 2, and 5 of the right hand but not digits 3 and 4 (Fig. 1-a). Spasticity of the right hand was classified as Modified Ashworth Scale (MAS) 1 for the flexor pollicis longus muscle, MAS 1 for the FDS and FDP muscles of digit 2, MAS 2 for the FDS muscle and MAS 1+ for the FDP muscle of digit 3, MAS 2 for the FDS muscle and MAS 1+ for the FDP muscle of

Toshiaki FURUKAWA, Department of Rehabilitation Medicine, Tokai University Hachioji Hospital, 1838 Ishikawa machi, Hachioji, Tokyo 192-0032, Japan
Tel: +81-426-39-1111 Fax: +81-426-39-1144 E-mail: furukawa.toshiaki@hachioji-hosp.tokai.ac.jp



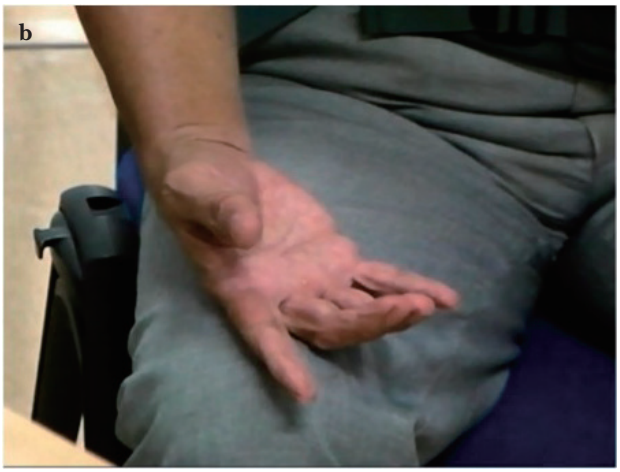
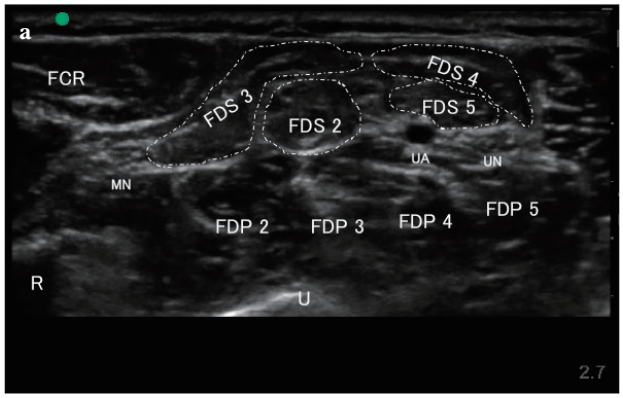
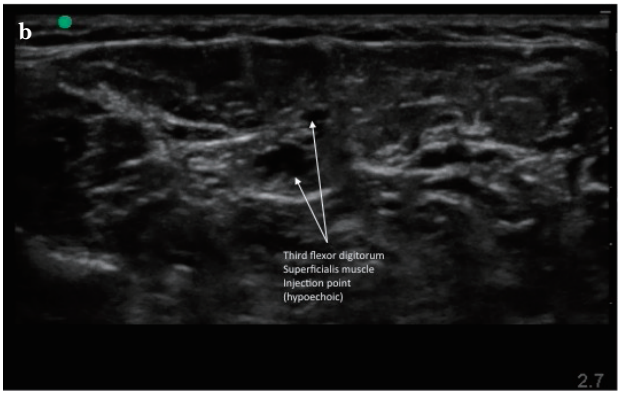


Fig. 1a: Although the extension of digits 1, 2, and 5 was possible, the extension of digits 3 and 4 was not possible.

b: At 2 weeks following injection, the contractures improved in digits 3 and 4, and separate movements of the digits became possible.

c: Ultimately, the subject was able to hold a paper cup containing water and bring it to his mouth.





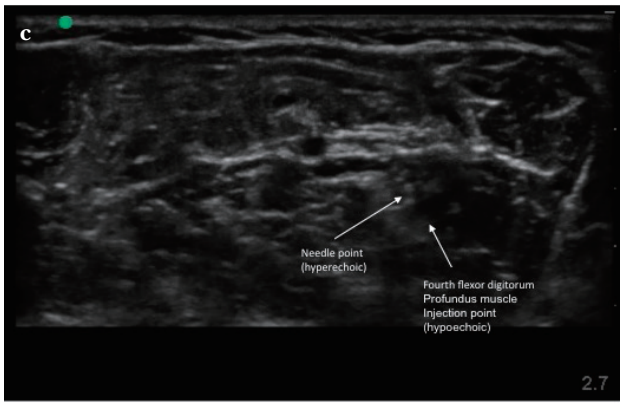


Fig. 2a: This diagram shows the positional relationship between the FDS, FDP, and FCR, and the median nerve, ulnar nerve, ulnar artery, radius, and ulna on ultrasound (short axis) of the central part of the forearm. The muscle belly of the FDS consists of a shallow layer and a deep layer, with tendons distributed from the shallow layer to digits 3 and 4 and from the deep layer to digits 2 and 5.
FDS; flexor digitorum superficialis , FCR; flexor carpi radialis, FDP; flexor digitorum profundus, MN; median nerve, UA; ulnar artery , UN; ulnar nerve, R; radius, U; ulna

b: This image shows an ultrasound that was taken at the time of the injection into the FDS of digit 3. The injection site in the FDS of digit 3 is seen as the region of low echo intensity.

c: This image shows an ultrasound taken at the time of the injection into the FDP of digit 4. The injection site in the FDP of digit 4 is seen as the region of low echo intensity. Furthermore, the needle tip is seen as the point of high echo intensity.

digit 4, and MAS 1 for the FDS and FDP muscles of digit 5. The MAS measures resistance during passive soft-tissue stretching and is used as a simple measure of spasticity. The MAS grades spasticity as follows: 0 = Normal muscle tone; 1 = Slight increase in muscle tone; 1+ = Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM; 2 = marked increase in muscle tone through most of the ROM, but affected part(s) easily moved; 3 = Considerable increase

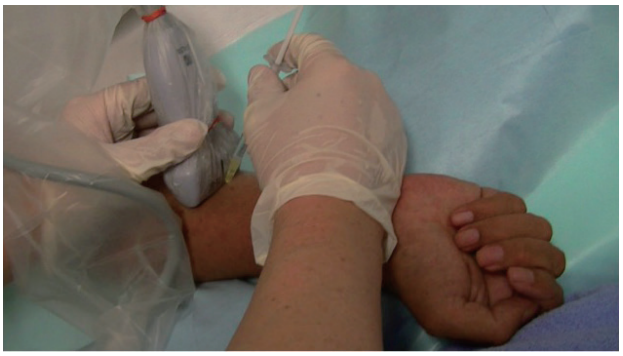


Fig. 3 This image shows the actual ultrasound-guided injection. Using a crossover approach, the puncture was made with the ultrasound probe and needle at an angle of 60°−80°.

in muscle tone, passive movement difficult; 4 = part(s) rigid in flexion or extension. The active range of motion was 0° for the proximal interphalangeal (PIP) joint extension and distal interphalangeal (DIP) joint extension of digits 2 and 5, -100° for the PIP joint extension of digit 3, -90° for the PIP joint extension of digit 4, -70° for the DIP joint extension of digit 3, and -60° for the DIP joint extension of digit 4.

On the Disability Assessment Scale (DAS), the scores were as follows: hygiene was 2, limb position was 3, pain was 0, and dressing was 1. Difficulties in ADL were assessed by using the DAS. Interview with each patient to determine the extent of functional impairment according to the following scale, 0: No disability. 1: Mild disability (noticeable but does not significantly interfere with normal activities). 2: Moderate disability (normal activities require increased effort and/or assistance). 3: Severe disability (normal activities limited). Hygiene: The extent of maceration, ulceration, and/or palmar infection; palm and hand cleanliness; ease of cleaning; ease of nail trimming; and the degree of interference caused by hygiene-related disability in the patient's daily life. Dressing: The difficulty or ease with which the patient could put on clothing (e.g., shirt, jacket, gloves) and the degree of interference caused by dressing-related disability in the patient's daily life. Limb position: The amount of abnormal position of the upper limb. Pain: The intensity of pain or discomfort related to upper limb spasticity. He was right handed but independent including eating by using the left hand and self-help tools. However, he could not perform actions that required the use of both hands because he was unable to extend digits 3 and 4 of his right hand and could only perform pinching movements with digits 1 and 2. He was unable to grasp with all the digits and, therefore, could not hold the steering wheel with the right hand when driving a car. He also could not grasp a rail and hold a cup or plate with both hands. Therefore, as a treatment plan, we decided to use ultrasound guidance to selectively identify the FDS and FDP muscles of digits 3 and 4 with strong spasticity and inject BoNT-A only into these sites. Identification and injection into the FDS and FDP muscles were performed using an ultrasound system (M-turbo; Sonosite, USA) and linear-transducer probe (HFL50×/15−6; Sonosite, USA). The patient was placed in the supine position on a bed and asked to maintain the most comfortable position with the elbow extended, with the forearm in the supine position to ensure a wide contact area of the skin with the ultrasound probe. The forearm was placed in maximum supination in a gentle and passive manner for identification. The probe was positioned in the central part of the forearm and then moved from the exact middle toward the ulnar side to find the best site to view the median nerve, ulnar nerve, and ulnar artery on B-mode imaging in the short axis. On the line connecting the median nerve, ulnar nerve, and ulnar artery, the upper half is the FDS and the lower half is the FDP muscle, below which the radius and ulna are partially depicted. At this site, the belly of the FDS muscle consists of a shallow and deep layer, and tendons are distributed from the shallow layer to digits 3 and 4 and from the deep layer to digits 2 and 5. The FDS muscle of the upper half is divided into four muscle bellies (FDS 2−5), whereas the FDP muscle of the lower half can be delineated as FDP 2−5, extending from the exact middle to the ulnar side (Fig. 2-a). Passive movement of the PIP and DIP joints in digits 2, 3, 4, and 5 enables confirmation of the muscle bellies and boundary zones of each of the four bellies of the FDS and FDP muscles. For the injection method, using a 23-G needle, an ultrasound-guided puncture was performed using the crossover approach (out of line), with the needle and ultrasound probe at an angle of 60°−80° (Fig. 3). The needle tip was slowly inserted while checking that the point of high luminance was at the intersecting point on the ultrasound beam. To begin with, injections were made at two sites where the central part of the target muscle, i.e., the FDS muscle of digit 3, was reached (Fig. 2-b). Next, the injection was performed where the needle tip orientation and depth changed to reach the central part of the FDP muscle of digit 3. Thereafter, an injection was performed into the FDS muscle of digit 4, the site where the needle tip orientation and depth changed to reach the central part of the FDP muscle of digit 4 (Fig. 2-c). The total BoNT-A dose was 150 U, with 60 U injected into the FDS muscle of digit 3, 40 U injected into the FDS muscle of digit 4, and 25 U injected into the FDP muscles of digits 3 and 4 (total, 50 U). Following the injections, rehabilitation training was conducted by occupational therapy for the digits and right arm once a week for 3 months. There were no complications observed at the time of injection or following the injection of the botulinum toxin formulation. Two weeks following the injections, the spasticity of the right digits had reduced to MAS 1 for the FDS and FDP muscles of digit 3 and MAS 1 for the FDS and FDP muscles of digit 4. There were no changes in the MAS 1 scores for the FDS and FDP muscles of digits 2 and 5 or for the flexor pollicis longus muscle of digit 1 (Table 1). Improvements in the active range of motion angles were observed to be -20° for the PIP joint extension of digit 3, -20° for the PIP joint extension of digit 4, -5° for the DIP joint extension of digit 3, and -5° for the DIP joint extension of digit 4 (Table2). Thus, extension had become possible for digits 3 and 4 (Fig. 1-b). After 4 weeks of continuous rehabilitation training, he was able to grasp with all of his digits and could hold the steering wheel with his right hand when driving a car. He was also able to grasp a rail with both hands, hold a cup, and bring the cup to the mouth (Fig. 1-c).

Table 1 Canges in FIM, MAS, DAS.

	Before	8weeks	12weeks	16weeks	20weeks
FIM Total score	112	116	116	116	116
DAS score					
hygiene	2	0	0	0	0
dressing	1	1	1	1	1
limb position	3	0	0	0	0
Pain	0	0	0	0	0
MAS score					
FDS and FDP muscles of digit 2	1	1	1	1	1
FDS muscle of digit 3	2	1	1	1	1
FDP muscle of digit 3	1+	1	1	1	1
FDS muscle of digit 4	2	1	1	1	1
FDP muscle of digit 4	1+	1	1	1	1
FDS and FDP muscles of digit 5	1	1	1	1	1

Table 2 Canges in ROM

	Before	8weeks	12weeks	16weeks	20weeks
PIP and DIP joint entension of digit 2	0°	0°	0°	0°	0°
PIP joint entension of digit 3	-100°	-20°	-20°	-20°	-20°
DIP joint entension of digit 3	-70°	-5°	-5°	-5°	-5°
PIP joint entension of digit 4	-90°	-20°	-20°	-20°	-20°
DIP joint entension of digit 4	-60°	-5°	-5°	-5°	-5°
PIP and DIP joint entension of digit 5	0°	0°	0°	0°	0°

FIM improved from 112 to 116 points, whereas, on the DAS , hygiene improved from 2 to 0 and limb position from 3 to 0 (Table 1). Assessments performed after 8, 12, 16, and 20 weeks indicated that the effects were maintained without any change in FIM, DAS, MAS, and range of motion.

DISCUSSION

Here, we report the effects of selective BoNT-A therapy on the FDS and FDP muscles for the treatment of flexion spasticity of the fingers. In the present case, the spasticity of the FDS and FDP muscles of digits 3 and 4 disturbed the motor function, which affected the subject's daily life. These muscles were selectively identified and injected. After the BoNT-A therapy, motor function was restored. In a small number of cases, the severity of spasticity of the FDS and FDP muscles in digits 2 to 5 varies between the digits after stroke. To treat such cases, it is important to correctly identify each target muscle and make accurate injections into these target muscles in BoNT-A therapy. In the present case, we performed ultrasound-guided identification and injection, which was safe and effective in terms of accuracy. With regard to the evaluation and therapeutic effects of injection techniques for spasticity of the wrist and digits following stroke, Henzel *et al.* [10] compared the identification of muscles using anatomical landmarks and palpation and ultrasonography to verify BoNT-A injection targets for spastic muscles of the forearm. They reported that ultrasonography was superior and therefore should be considered in verifying the position of the muscles. Santamato *et al.* [11] performed manual needle placement using surface anatomical landmarks or ultrasound guidance in 30 patients. They reported that after 1 month, when MAS and finger position at rest were assessed, ultrasound guidance was superior to surface anatomical landmarks. Furthermore, Picelli *et al.* [12] verified the accuracy of manual needle placement using surface anatomical landmarks for the forearm muscles (flexor carpi radialis, flexor carpi ulnaris, FDS, and FDP) using ultrasonography and reported an overall accuracy of 61% and 65.9% for the FDS and FDP muscles, respectively. Therefore, the accuracy and effectiveness of ultrasound injection techniques have been verified. However, although these previous reports included the FDS and FDP muscles, the four muscle bellies were not separately identified, and accordingly, selective injections into the muscle belly were not performed. In this patient, we think that better results can be achieved when aiming to restore motor function by separating and identifying the four muscle bellies of the FDS and FDP muscles as injection targets. The benefits of ultrasound-guided injection include effectiveness in terms of accuracy and outcome and safety. In the present case, we were able to advance the needle tip while verifying the location of the median nerve, ulnar nerve, and ulnar artery using ultrasound guidance at the same time. This avoided damage to the nerves and blood vessels, and we were able to safely and accurately perform the injections. Both the FDS and FDP muscles of digits 3 and 4 were injected once, and therefore, a relatively long 23-G needle (0.6 mm in diameter and 25 mm in length) was used. The aim

of this was to decrease the number of injections and reduce the pain as much as possible during injections. Santamato *et al.* [11] selected a 25-G needle for injection. However, if the needle is used for injections into the four bellies of the FDS muscle, we find that sufficient depth can be achieved even using a 30-G needle (diameter, 0.3 mm, and length, 19 mm), and treatment can be administered with less pain at the time of puncture. With regard to the ultrasound-guided injection method, we performed the puncture and injection using an out-of-line approach. With this approach, the puncture angle is greater compared with the inline approach, and the needle can reach the muscle via a shorter distance. This also has the advantage of avoiding the use of a long needle. Although the identification of the needle tip can be difficult, by moving the needle tip up and down to attain high luminance at the intersecting point on the ultrasound beam, the injection site of the needle can be confirmed. Therefore, we used this injection technique. In the present case, by selectively identifying muscles and treating spasticity, we were able to attain voluntary movement of the fingers. Moreover, movements needed for ADL were restored by occupational therapy and through task-oriented intensive training; we were able to restore the functions of the patient's right hand, which he had not used for a long time. In conclusion, injection techniques by ultrasound guidance facilitate the accurate separation and identification of individual target muscles. Then, it can improve the accuracy of the site of BoNT-A injection. Furthermore, injection into the blood vessels and nerves can be avoided. Thus, BoNT-A can be more safely and effectively administered. In the present case, with the use of selective BoNT-A and occupational therapies for muscle spasticity of the FDS and FDP muscles of digits 3 and 4, we were able to restore function of the fingers and improve ADL. In the future, it is anticipated that more selective injections, taking into account ultrasound imaging of optimal sites, will become necessary when performing injections to target spastic muscles.

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