Half-mirror biofeedback exercise in combination with three botulinum toxin A injections for long-lasting treatment of facial sequelae after facial paralysis

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KEYWORDS
Facial palsy; Botulinum toxin; Rehabilitation; Biofeedback exercise

Summary  Objectives/hypothesis: The present study was conducted to develop a new method for maintaining the effect of botulinum toxin treatment for facial sequelae. We used a combination strategy including the administration of botulinum toxin three times at 6–8-month intervals followed by daily newly developed half-mirror biofeedback rehabilitation for about 2 years from the first injection.
Study design: This was a prospective study.
Methods: Seventeen patients with unilateral facial palsy for >1 year were included in the study. The amount injected per site varied from 1.5 to 3 U. The purpose of the first injection was to reduce the most inconvenient facial problem such as facial synkinesis or hyperkinetic movement at the points of the periocular area and the zygomaticus major and minor muscles with an average dosage of 17.4 ± 13.9 U. The second injection was to enhance facial symmetry at prominent hypertrophic areas on the contralateral side with 36.5 ± 15.4 U, and the third injection was to add cosmetic configuration at the points of deep furrows and creases caused by facial muscular hyperkinesis or atrophy with 15.6 ± 8.4 U.
Result: After three injections of botulinum toxin A and 2 years of half-mirror biofeedback exercises, all patients showed marked relief of facial synkinesis and facial asymmetry. Before treatment, the mean ± standard deviation (SD) Sunnybrook (SB) score was 36.8 ± 8.76. After the first injection, the score increased by 11.4. After the second injection, the score increased by 14.6; it further increased by 15.6 after the third injection.

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Conclusion: This facial rehabilitation strategy, consisting of three injections of botulinum toxin and half-mirror biofeedback exercises, proceeds over the course of 2 years and offers a long-lasting cure for facial synkinesis and facial symmetry as well as improved facial aesthetics. © 2014 British Association of Plastic, Reconstructive and Aesthetic Surgeons. Published by Elsevier Ltd. All rights reserved.

Introduction

In addition to functional problems, patients with facial paralysis experience self-consciousness about their disfigurement and profound psychological distress.1,2 As one of the most unpleasant sequelae of acute facial paralysis, facial synkinesis is known to be caused by aberrant facial nerve regeneration of fibers in the neural repair process.3 It is defined as the presence of unintentional motion in one area of the face produced during intentional movement in another area of the face.4,5 The most common symptoms of facial synkinesis are either involuntary eye closure with volitional mouth movements (oral–ocular synkinesis) or involuntary contraction of cheek muscles with volitional eye closure (ocular–oral synkinesis).6 When such a synkinesis occurs, facial hyperkinesis, which consists of static and dynamic asymmetry of the face due to hypertonia, can also develop as another undesired secondary effect of recovery from facial paralysis.7

The aesthetic qualities of patients with such facial sequelae are frequently compromised by asymmetry. The non-paralyzed side, which chronically acts against the weak antagonism of the contralateral muscles, usually presents with facial muscular hypertrophy, wrinkles, furrows, and deviation of the mouth. Facial changes associated with facial sequelae can be attributed to “unbalanced” muscular activity, “unbalanced” muscular hypertrophy, and an “unbalanced” pattern of facial expression. The whole picture can become worse over time. Therefore, for some patients, progressive facial asymmetry, more than synkinesis, can lead to low self-esteem and poor quality of life with aging.6,9

For more than two decades, botulinum toxin has improved the management of patients with facial movement disorders. It is now a first-line agent for the treatment of facial synkinesis and hyperkinesis. The application of botulinum toxin to the healthy side of the faces of patients with long-standing facial paralysis is a minimally invasive technique that improves the symmetry of the face at rest and during facial motion.10–13 Additionally, it has been reported that weakening of the non-paralyzed side allows structures on the paralyzed side to strengthen and improve functionally.14 However, in most patients, the effectiveness of the botulinum toxin decreases over time. This diminishing effect may be the result of the rerouting of motor end plates or the development of neutralizing antibodies and cannot be overcome with increased doses of the toxin.15

However, together with facial synkinesis and hyperkinesis, loss of strength and loss of isolated motor control can occur in the paralyzed face several months after facial paralysis, and this and cannot be overcome easily. Although several physical exercises are known to be effective for increasing muscular strength, little evidence that facial exercises improve facial strength is available.

Therefore, we combined mirror biofeedback exercises with botulinum toxin injections to maintain the effect of the botulinum toxin over an extended period and to enhance the effects of physical exercise as reported by Azuma T et al.16 However, the classic mirror biofeedback exercise has a number of disadvantages.17 Exercise is disturbed by movement of the non-paralyzed side, and patients may find it difficult to compare the paralyzed and non-paralyzed sides. To overcome the disadvantage of the mirror exercise, a new mirror exercise method, known as half-mirror biofeedback, was developed.

The present study was conducted to develop a new method for maintaining the effect of botulinum toxin treatment for facial sequelae. We used a combination strategy including the administration of botulinum toxin three times at 6–8-month intervals followed by daily half-mirror biofeedback rehabilitation for about 2 years.

Materials and methods

Seventeen patients (10 women and seven men) with unilateral facial palsy for ≥1 year were included in the study. All had static and/or dynamic facial asymmetry causing concerns about the aesthetics of the face. The patients ranged in age from 34 to 62 years (mean = 49.3 ± 5.1 years). The time before onset of synkinesis was 5.3 months (4.5–6 months) after facial paralysis, and the interval between the onset of facial palsy and botulinum toxin A injection ranged from 14 to 84 months, with a mean of 26 months. All patients showed severe oral–ocular or ocular–oral synkinesis and contralateral compensatory muscular hypertrophy, and were evaluated with the Sunnybrook (SB) facial nerve grading systems by two investigators.

All facial expression muscles or groups of muscles on both sides were dynamically examined including facial synkinesis such as involuntary eye closure with volitional mouth movement or involuntary contraction of cheek muscles with volitional eye closure, compensative facial muscular hypertrophy on the contralateral side, and deepened facial wrinkles or folds. An ice pack was applied for vasoconstriction prior to local anesthesia. The purpose of the ice pack prior to anesthesia is to reduce injection pain, longer effectiveness of Botox, and lessen bleeding from the injection point.

Botulinum toxin A (Botox®; Allergan Incorporated, Irvine, CA, USA) was injected using a tuberculin syringe.
with a 27-gauge needle. The amount injected per site varied from 1.5 to 3 U, and the total dose used per patient was 17.4 ± 13.9 at first injection, 36.5 ± 15.4 at second injection, and 15.6 ± 8.4 at third injection, with an interval of 6–8 months. The purpose of the first injection was to reduce the most inconvenient facial problem such as hyperlacrimation, facial synkinesis, or hyperkinetic muscular movements; the second injection was to lessen a facial asymmetry induced by facial muscular atrophy on the paralyzed side or compensative muscular hypertrophy on the non-paralyzed side; and the third injection was to add a cosmetic configuration with correction of deep nasolabial folds, hypertrophic crease on forehead, crow’s feet, or bitterness furrows. The points of injection (2.5 U of botulinum toxin A per point) for the oral–ocular synkinesis or ocular–oral synkinesis were designed at the periocular and perioral areas and included the zygomaticus major and minor muscles (Figure 1-A). The points of injection (3 U of botulinum toxin A per point) for facial asymmetry caused by contralateral compensatory muscular hypertrophy were designed at prominent hypertrophic or hyperkinetic areas on the contralateral side (Figure 1-B), and the points of injection (1.5–2.5 U of botulinum toxin A per point) for adding cosmetic configuration were designed at deep furrows and creases caused by facial muscular hyperkinesis or atrophy (Figure 1-C).

After the first injection of botulinum toxin, patients started the newly developed rehabilitation method (half-mirror biofeedback exercise). The patients were instructed to look at the lens of a camera and to concentrate on three designated eye movements (eyelid closure with minimal effort, eyelid closure with maximal effort and look at over), three mouth movements (say "e," "o," and blowing a balloon), and gross facial picture at rest. The photographs taken with seven facial expressions of the patient were rotated on a horizontal plane, and the normal side of the face in the pictures was extracted. With the normal side of the face in the mirror (half-mirror) covered, the patient

Figure 1  A. The points of injection (2.5 U of botulinum toxin A per point) for oral–ocular synkinesis or ocular–oral synkinesis were designed at the periocular area and perioral area and included zygomaticus major and minor muscles, B. The points of injection (3 U of botulinum toxin A per point) for facial asymmetry caused by contralateral compensatory muscular hypertrophy were designed at prominent hypertrophic areas on the contralateral side, C. The points of injection (1.5–2.5 U of botulinum toxin A per point) for adding cosmetic configuration were designed at deep furrows and creases caused by facial muscular hyperkinesis or atrophy.
was able to directly compare the weakened side of the face with the normal side while making several expressions for the exercise of dynamic movement of the face with static pictures (Figure 2-A, B).

The half-mirror exercise allows for the direct visualization of facial movement on the non-paralyzed side. It does not disturb the facial movement of the non-paralyzed side after shielding and also facilitates effective concentration on the facial muscles of the paralyzed side after covering the normal side of the face. Patients were advised to perform the rehabilitation exercise at home for 30 min per day for 2 years. The patients visited our department once every 2 months for follow-up of their compliance with the rehabilitation instructions and evaluation of their facial movement. The therapeutic effect after 2 years was evaluated with the Sunnybrook (SB) facial nerve grading system.

Results

After three injections of botulinum toxin A and 2 years of half-mirror biofeedback exercises, all patients showed marked relief of facial synkinesis and facial asymmetry. Before botulinum toxin A treatment and half-mirror exercise, the mean ± standard deviation (SD) SB score was 36.8 ± 8.76. After the first injection, the score increased by 11.4. After the second injection, the score increased by 14.6; it further increased by 15.6 after the third injection. However, there was a limit to the effect of botulinum toxin A treatment and half-mirror exercise (Figure 3-A, B, C).

A total of 506 injections were administered in various facial regions (the mean number of injections for each patient was 29.8 for 2 years). The injected facial muscles are shown in Figure 4-A, B. To control synkinesis, the glabellar, orbicularis oculi, nasalis, upper lip levator, risorius, and orbicularis oris muscles were injected. To decrease hypertrophy of the contralateral facial muscles, the frontalis, glabellar, nasalis, orbicularis oculi, upper lip levator, risorius, lower lip depressor, and orbicularis oris muscles were injected. Four patients had adverse reactions, including hematoma at the injection site, ptosis, and diplopia that lasted for 6 weeks.

Discussion

It has been shown that there is no clearly effective intervention modality for patients who inevitably develop facial sequelae, and mixed results have been obtained with respect to most treatment approaches. Thus, it is difficult for facial nerve function to recover completely once facial synkinesis has occurred.

Numerous facial rehabilitation techniques for facial problems associated with facial palsy have been developed to improve cosmesis and function, including eyelid gold weight, brow lifts, orbicularis myectomy, and medial canthoplasty. However, botulinum toxin A chemical neurectomy has recently been considered a good approach for treating facial sequelae. Although botulinum toxin injection has shown remarkable results within a few days with respect to the disappearance of facial synkinesis, the effect lasts only 3–5 months. The temporary nature of the therapeutic benefit of facial sequelae treatment with botulinum toxin is a serious disadvantage.

To prolong the effect of the botulinum toxin, we combined this therapy with mirror biofeedback exercises. The combination of mirror biofeedback exercise and botulinum toxin offers many synergistic advantages. During the period when botulinum is effective, patients can train their defective facial muscles with mirror exercises.

The half-mirror biofeedback exercise was designed to enhance the effects of physical therapy and prolong the effective period of botulinum toxin treatment. Existing mirror biofeedback exercise methods have some advantages. First, it is very effective to train to isolate and control the muscular movement correctly. Additionally, daily self-training using only a mirror is also easy for patients to learn. However, the exercise is disturbed by the movement of the non-paralyzed side of the face, and it is difficult to compare the paralyzed side with the non-paralyzed side. To overcome these disadvantages, half-mirror biofeedback exercises, in which the patient can directly compare the weakened side of the face with the

Figure 2  A. A photograph of the patient was rotated vertically, and the normal side of the face in the picture was extracted. With the normal side of the face in the mirror (half-mirror) covered, the patient was able to directly compare the weakened side of the face with the normal side while making facial expressions, B. After the first injection of botulinum toxin, patients started the half-mirror biofeedback exercise for about 2 years.
normal side while making various facial expressions, were developed. The advantages of the half-mirror exercise are listed below. First, it allows direct visualization of the facial movement on the non-paralyzed side. Second, it does not disturb the facial movement on the non-paralyzed side after shielding. Third, it facilitates effective concentration on facial muscles on the paralyzed side after shielding. Fourth, it maximizes the therapeutic effects of botulinum toxin. Finally, it is easy to learn with self-training and is inexpensive.

The past method of the mirror biofeedback exercise has some disadvantages. This exercise is disturbed by facial movement of the non-paralyzed side and it is difficult to compare the paralyzed side with the non-paralyzed side. This present protocol using the half-mirror biofeedback exercise with Botox has many synergistic advantages. First, Botox weakens the healthy-side, half-mirror developed muscles of the paralyzed side. Second, Botox can control synkinesis and the half-mirror exercise trains fine isolated muscles, and then it provides an increase of isolated motor control. Third, Botox can inhibit contralateral hypertrophy, and the half-mirror exercise inhibits muscular atrophy of the paralyzed side and provides improvement of facial symmetry. Lastly, Botox can control hyperkinetic movement, and the half-mirror exercise relaxes hyperkinetic movement and then provides control of involuntary movement.

The purpose of the first injection is to decrease most functional deficit on the non-paralyzed side. Most patients want to reduce the synkinetic facial movement between the oral and ocular areas with removal of hyperlacrimation. In most cases, the long-term therapeutic effect on oral–ocular synkinesis is thought to be due to a combination of temporary recovery from synkinesis as a result of botulinum toxin and a gradual decline in synkinesis over several months due to half-mirror biofeedback rehabilitation. Facial biofeedback rehabilitation with a half-mirror alone is thought to have no effect on facial synkinesis because the therapeutic effect depends on the preceding botulinum toxin injection.

The second injection, given 6–8 months after the first injection, and continued half-mirror exercises enhance facial symmetry. Most patients with facial sequelae frequently have their aesthetics compromised by asymmetry, even after successful control of synkinesis. Changes associated with facial sequelae can be attributed to “unbalanced” muscular activity, “unbalanced” muscular hypertrophy, and “unbalanced” facial expression patterns as the non-paralyzed side, which chronically acts against the weak antagonism of the contralateral muscles, and usually presents with facial muscular hypertrophy, wrinkles, furrows, and deviation of the mouth. The whole picture can worsen over time. Therefore, in some patients, progressive facial asymmetry rather than synkinesis can lead to low self-esteem and poor quality of life with aging. Although this second procedure helps the patient to achieve facial symmetry, some limitations were observed on dynamic facial movement. However, this procedure does not induce any functional deficit on the non-paralyzed side. Unlike the rapid and temporary therapeutic effects of ipsilateral injection only, it has frequently been reported that the application of botulinum toxin to the contralateral non-paralyzed muscles in combination with the ipsilateral paralyzed muscles results in a long-lasting decline in oral–ocular synkinesis. It has also been reported that the strength of paralyzed muscles and control over fine isolated facial movements can be gradually enhanced by reducing the strength of the normal side. Further studies are needed to establish the “strength redistribution phenomenon” induced by the aforementioned contralateral muscular botulinum toxin injection.

The third injection, given 6–8 months after the second injection, and continued half-mirror exercises are used to enhance the cosmetic configuration. This third procedure involves minor surgery or procedures, including brow lifts, canthoplasty, and botulinum toxin or filler injections for creases and furrows caused by hyperkinesia, loss of strength, and loss of isolated motor control after facial paralysis. This procedure helps patients to recover their self-esteem and improves their quality of life. In our cases, two patients underwent brow lifts, two patients underwent injections of filler for deepened nasolabial folds, and one patient underwent canthoplasty.

The therapeutic effect of this study can be compared by review of previous other reports that were well designed for the identification of the therapeutic effect of Botox or rehabilitation alone. Most of the previous studies examining the therapeutic effect of Botox for facial sequelae have shown remarkable results in the disappearance of facial synkinesis within few days but the effect lasts only 3–5 months. In addition, many reports about the effect of facial exercise for facial sequelae have been proven to have low-quality evidence by systemic reviews. The facial improvement after cessation of all treatment is somewhat varied depending on the patients’ facial status at the beginning of treatment or their cooperation on physical therapy. The exact period of treatment is hard to say to be 2 years, but the average period of treatment until facial improvement as we had intended initially was about 2 years. Most patients experienced an improvement of facial movement after 2 years. If their symptoms remain after 2 years, we will continue this therapy using Botox injection with physical therapy or enhance cosmetic configuration. We think that the effectiveness of the treatment is more important than the duration of the treatment period being 2 years. In addition, the period of stable facial status was about 2 years after the application of this strategy. We observed decreased facial synkinesis that did not require management with any injection or physical therapy any more after about 2 years. Although patients with postaparetic facial synkinesis (PPFS) did not undergo complete recovery from chronic facial paralysis, their symptoms and discomfort had almost disappeared after 2 years of this strategy. Two years could be considered the optimal period for evaluation of the final effectiveness of this therapy. In addition, the number of times the injection was administered did not matter. Four or more injections could just be considered to be optimal because there are various results depending on the patients’ facial status. This strategy should be considered as a flexible pattern and not a rigid one.

Together with facial synkinesis and hyperkinesia, loss of strength and loss of isolated motor control can be improved in the paralyzed face with the combination therapy of half-
Figure 3  A. After three injections of botulinum toxin A and 2 years of half-mirror biofeedback exercises, all patients showed marked relief of facial synkinesis and facial asymmetry. Before botulinum toxin A treatment and half-mirror exercise, the mean ± SD SB score was 36.8 ± 8.76. After the first injection, the score increased by 11.4. After the second injection, the score increased by 14.6; it further increased by 15.6 after the third injection, B. The patient had oral—ocular synkinesis on the left side and contralateral muscular hypertrophy on the right side after the onset of severe facial paralysis 2 years ago. Following the first injection of Botox and half-mirror exercises, synkinesis decreased after 8 months. After the second injection and exercise, her face was more symmetrical than it was before. After the third injection on the nasolabial fold and additional exercise, her face was more beautiful and did not exhibit synkinesis or asymmetry, C. The patient had oral—ocular synkinesis on the left side and contralateral muscular hypertrophy on the right side after facial nerve reconstruction due to parotid cancer 2 years ago. Six months after the first injection of Botox and half-mirror exercises, she had decreased synkinesis. After the second injection and additional exercise, she had a more symmetrical face than she had prior to the treatment. After the third injection on the nasolabial fold, blepharoplasty on the upper eyelid and half-mirror exercises, she had better face than before, which was devoid of synkinesis or facial asymmetry.
mirror biofeedback exercise and botulinum toxin 2 years after facial paralysis. The whole picture can become better over time. The aesthetic qualities of patients with such facial sequelae are getting better by the correction of facial synkinesis and asymmetry and by enhancing cosmetic configuration.

Conclusion

Half-mirror biofeedback rehabilitation designed for facial sequelae shows good results in combination with botulinum toxin therapy. This facial rehabilitation strategy, consisting of three injections of botulinum toxin and half-mirror biofeedback exercises, proceeds over the course of 2 years and offers a long-lasting cure for facial synkinesis and facial symmetry as well as improved facial aesthetics.

Ethical approval

Not required.

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Conflicts of interest

None declared.

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