

Paradoxical Use of Frontalis Muscle and the Possible Role of Botulinum A Toxin in Permanent Motor Relearning

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Purpose: To report 7 patients with paradoxical use of the frontalis muscle despite postsurgical correction of ptosis with good postoperative eyelid position. Successful treatment with botulinum A toxin facilitated motor relearning and cessation of muscle contraction.

Design: Interventional case series.

Participants: Seven patients, in 2 eye-plastic clinics, who underwent successful surgical correction of upper eyelid ptosis.

Methods: Review of clinical history, clinical photographs, treatment, and follow-up.

Main Outcome Measures: Frontalis muscle contraction and upper eyelid position.

Results: Patients underwent successful surgical correction of ptosis but continued using the frontalis muscle despite good eyelid position postoperatively. Frontalis contraction ceased spontaneously in 2 patients, but required botulinum A toxin injection in 5. The effects of a single treatment of botulinum A toxin lasted from 3 months to 2 years, longer than the expected effect of the toxin.

Conclusion: Patients with long-standing eyelid ptosis may paradoxically continue utilizing the frontalis after successful surgical correction and despite good postoperative eyelid position. Cessation of frontalis contraction can be achieved with a single injection of botulinum A toxin. We hypothesize that chemodenervation, achieved with the toxin, may influence the central nervous system to relearn the set point for muscle contraction and may be associated with permanent motor relearning. Spontaneous resolution of muscle contraction can occur in the first months after surgery. *Ophthalmology* 2005;112:918–922 © 2005 by the American Academy of Ophthalmology.

In the last decade, pharmacotherapy has made significant advances in the treatment of spasticity, with botulinum A toxin (Botox, Allergan Pharmaceuticals, Irvine, CA) being one of the more popular agents. The toxin acts by inhibiting the release of acetylcholine from vesicles at the presynaptic nerve terminal at the neuromuscular junction (chemodenervation). Muscle weakness may not become evident for 2 to 4 days due to the continued release of acetylcholine from vesicles that have not yet been blocked by the toxin. Restoration of muscle activity typically begins 3 to 4 months after the injection due to regeneration of new endplate units.¹ Given IM, botulinum A toxin results in temporary chemodenervation and the loss or reduction of neuronal activity at the target muscle.^{2,3}

Botulinum toxin reduces muscle contractility and has

been used to treat many medical conditions, including reduction of forehead wrinkles caused by chronic scalp muscle contraction. Additional therapeutic indications for botulinum toxin injection include strabismus, acquired nystagmus, myokymia, spastic lower lid entropion, spastic dysphonia, aberrant regeneration of the seventh cranial nerve, spasmodic torticollis, corneal ulcer, corneal exposure, hemifacial spasm, and essential blepharospasm.^{4–7}

Neuronal plasticity plays pivotal roles in recovery from injury and in learning/memory in both the peripheral and the central nervous system.⁸ Neuroparalysis produced by botulinum A toxin elicits nerve sprouting, and the newly created synapses are responsible for the initial synaptic transmission at the onset of recovery from muscular paralysis.^{9,10}

Many patients with long-standing upper eyelid ptosis use their frontalis muscles as a compensatory mechanism to achieve a wider palpebral fissure and improved peripheral vision. Interestingly, after successful surgical correction of upper eyelid ptosis, patients still use their frontalis muscle despite good eyelid position postoperatively. This may subside spontaneously months after surgery, lasting in some patients indefinitely. Not uncommonly, patients are aware of this phenomenon but still continue using the forehead unconsciously.

The purpose of the current study was to report 7 patients with paradoxical use of the frontalis muscle

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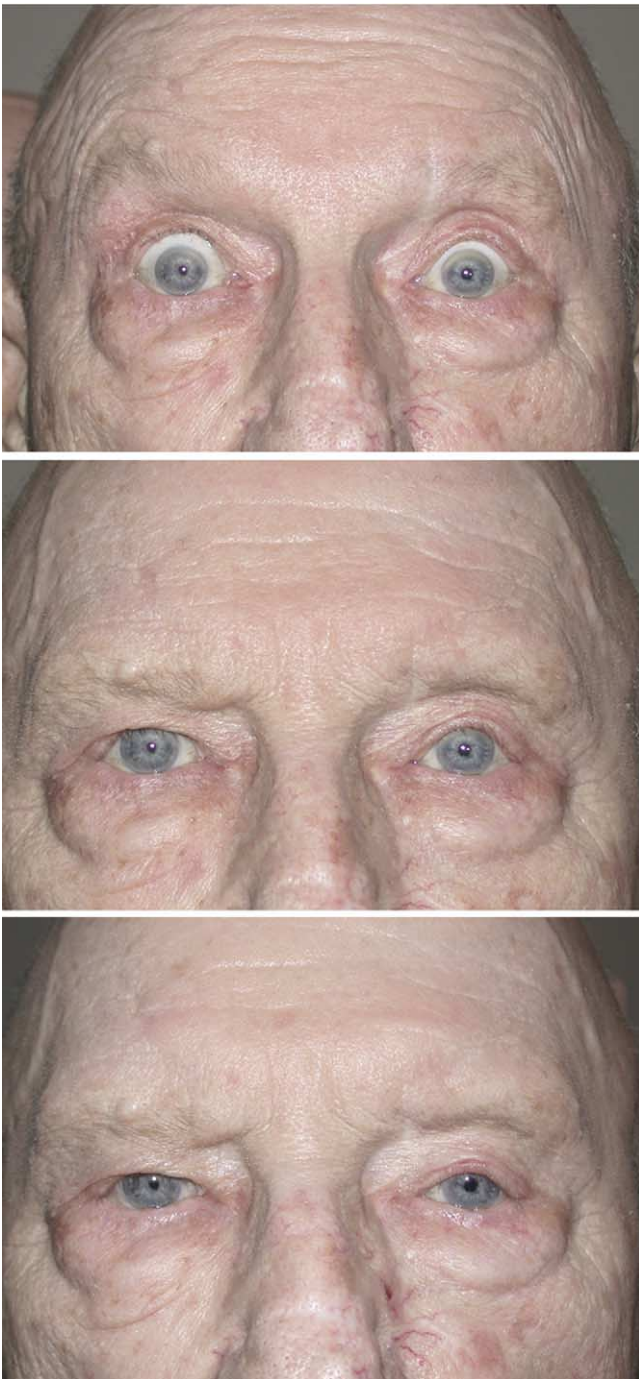


Figure 1. **Top,** An 82-year-old male 2 months after bilateral upper eyelid ptosis surgery and upper blepharoplasty. Despite good upper eyelid position, the patient continued to recruit the frontalis unconsciously, resulting in near constant and exaggerated retraction of both upper eyelids. **Middle,** One month after botulinum A toxin injection to the frontalis muscle on both sides. **Bottom,** Twenty months after a single injection of botulinum A toxin, the patient continued to have a constant and adequate upper eyelid level, with no return to pre-botulinum A toxin injection hyperactivity of the frontalis muscle. There seemed to be retraining of motor activity to the frontalis, and no additional treatment with botulinum toxin was indicated.



Figure 2. A 39-year-old female was referred to our outpatient clinic for asymmetric upper eyelids. Ophthalmic history revealed a motor vehicle accident that caused a left orbital fracture for which she was operated several times 19 years before admission. She also underwent several eyelid surgeries on both sides in an attempt to achieve a symmetrical appearance. **Top,** Ptosis of the right upper eyelid that was partially compensated by lifting of the right eyebrow. **Middle,** One year after botulinum A toxin injection to her right frontalis muscle to improve eyelid symmetry. The effect of botulinum A toxin injection was sustained 1 year postoperatively with mild recruitment of the frontalis muscle. **Bottom,** Several months after left endoscopic browlift, with good cosmetic results.

despite successful ptosis surgery. Four patients underwent treatment with botulinum A toxin injection with long-lasting effect; in 3 patients, the frontalis contractions subsided spontaneously.

Case Reports

Patient 1

An 82-year-old male presented with functional bilateral upper eyelid ptosis resulting in obscuration of his superior visual fields. Preoperatively, he was heavily recruiting his frontalis muscle to see. The patient underwent bilateral upper eyelid blepharoplasty and external levator advancement. Two months postoperatively, he presented with a slightly elevated left upper eyelid relative to the right when the frontalis muscle was relaxed. However, the patient continued unconsciously to recruit the frontalis, resulting in near constant and exaggerated retraction of both upper eyelids (Fig 1, top). This was brought to the attention of the patient; however, after 4 months he continued to have persistent upper eyelid retraction, causing ocular irritation and punctate epithelial keratopathy. Options presented to the patient included surgical lowering of the eyelids closer to preoperative levels, leaving the patient ptotic when the forehead is relaxed, or botulinum A injections targeting the frontalis muscle, in effect lowering the brows. It was explained that, although the botulinum A would relieve the frontalis hyperactivity, he would likely require repeat injections. The patient opted not to proceed with either of these options, but despite vigorous ocular lubrication, his exposure keratopathy worsened.

One year postoperatively, the patient consented to botulinum A toxin injections to the frontalis muscle bilaterally. Seven injections of 1.25 U were given on each side, staying 1.5 cm above the orbital rims and medial to the temporal line. On follow-up examination a month later, the patient had an adequate and constant upper eyelid level (Fig 1, middle), except for some persistent overcorrection in the left upper eyelid, for which he had revision surgery 2 months later. Due to the surgeon's (SMB) deployment to the Middle East, the patient was not seen again until 10 months later (2 years and 10 months from first surgery and 20 months after having the forehead injected with botulinum A injection). At that time, the patient continued to have a constant and adequate upper eyelid level, with no return to pre-botulinum A toxin injection hyperactivity of the frontalis muscle (Fig 1, bottom). There has seemed to be retraining of motor activity to the frontalis, so no additional treatment with botulinum toxin was indicated. There was no exposure keratopathy, and the patient was satisfied with the resultant eyelid position, despite some eyelid asymmetry.

Patient 2

A 39-year-old female was referred to our outpatient clinic because of asymmetry in the upper eyelid appearance. Ophthalmic history revealed a motor vehicle accident that caused a left orbital fracture for which she was operated several times 19 years before admission. She also underwent several eyelid surgeries bilaterally in an attempt to achieve a symmetric appearance. Medical history revealed hyperthyroidism with radioactive iodine therapy. Current medical therapy consisted of thyroid hormone replacement. On clinical examination, she had visual acuity (VA) of 20/25 in both eyes, and anterior and posterior segments were unremarkable. She had ptosis of her right upper eyelid, which was partially compensated by lifting her right eyebrow (Fig 2, top). Levator function was 11 mm on the right and 15 mm on the left. There was some weakness of her orbicularis in both eyes, and cicatricial ectropion of her left lower eyelid. She had a mild limitation of the upgaze in her left eye. Exophthalmos measurements showed relative proptosis of 19 mm on the right side and 16 mm on the left.

She received botulinum A toxin injection to her right frontalis

muscle to improve eyelid symmetry. Three months after injection, there was improved eyebrow symmetry because the right eyebrow came down. The right upper blepharoptosis persisted, however. The effects of the botulinum A toxin remained 1 year postoperatively, with mild recruitment of the frontalis muscle (Fig 2, middle).

In an attempt to improve symmetry, the patient was treated with guanethidine eyedrops to her left eye to lower the left upper eyelid. One and a half years after initial presentation, she underwent an endoscopic browlift on the left side, with good cosmetic results (Fig 2, bottom).

Patient 3

A 46-year-old male presented to our clinic with a 2-year history of progressive ptosis, with the right upper eyelid worsening in the evening. Ophthalmic history was unremarkable, with no previous ocular surgery or contact lens use. Clinical examination disclosed uncorrected VAs of 20/20 (right eye) and 20/25 (left eye). There was right upper eyelid ptosis with moderate to good levator function (Fig 3, top). The patient underwent right levator aponeurosis resection with moderate to good improvement in eyelid position but residual ptosis (Fig 3, middle). The patient underwent a second ptosis correction via conjunctivomullerectomy (Putterman) 5 months after the original surgery.

The patient kept using the frontalis muscle after the first surgery due to residual ptosis, but a short while after the second surgery he ceased using the frontalis muscle on the right side (Fig 3, bottom).

Two additional patients were treated with botulinum A toxin injection for prolonged frontalis muscle contraction after upper eyelid ptosis correction and despite good eyelid position, with the effect lasting 8 months postoperatively. In another patient, the use of the frontalis muscle subsided spontaneously 2 months postoperatively with no further treatment. One patient received botulinum A toxin injection for paradoxical elevation of the right eyebrow despite right upper eyelid retraction and after successful surgical correction of eyelid retraction. On examination 3 months after the injection, the patient had ceased utilizing the frontalis muscle on the injected side.

Discussion

This report demonstrates permanent motor relearning of alleviating the use of the frontalis muscle in patients with good eyelid position after successful surgery for eyelid ptosis. Paradoxical use of the frontalis muscle probably reflects the long-standing nature of the preoperative status to a point that it becomes subconscious. In most patients, frontalis muscle contraction ceases spontaneously once patients achieve good eyelid position; however, others may need treatment with botulinum A toxin. Surprisingly, although chemoparalysis of the muscle with botulinum is temporary, our patients did not return to preoperative use of the muscle, possibly as a result of permanent motor relearning. Interestingly, one of the patients had low vision in both eyes, and the role of visual stimulation in causing frontalis muscle contraction in this case is unclear. This phenomenon is also observed in patients with anophthalmic socket and a prosthetic eye, where ptosis itself may be the only stimulator for frontalis muscle use.

Botulinum toxin inhibits release of acetylcholine from the neuromuscular junction, resulting in localized paralysis.



Figure 3. Top, A 46-year-old male with right upper eyelid ptosis. Middle, Two months after external levator advancement, with residual ptosis on the right with compensatory brow elevation. Bottom, Ten months after second ptosis correction on the right (conjunctivomullerectomy), with good functional and cosmetic results. The patient had stopped using the frontalis muscle on the right side shortly after the second surgery.

The resulting muscle paralysis provides the botulinum toxin therapy. Clinical uses include blepharospasm, hemifacial spasm, glabellar wrinkles, strabismus, and cervical dystonia. It has even been suggested that alleviating the symptoms of focal dystonia may be associated with pain relief associated with this disorder.¹¹ The inhibition of neuromuscular signal transfer is long lasting but temporary, and is especially important in patients where limited paralysis is desired. Such is the case of nonconcomitant strabismus in traumatic sixth nerve palsy, where unopposed action of an intact medial rectus muscle results in large-angle esotropia. Sub-Tenon's capsule injections of botulinum toxin weakens

the medial rectus muscle and results in recovery of the strabismus in >50% of patients. It also has limited success in consecutive and secondary exotropia.^{12,13} Botulinum toxin type A has also been reported to reduce spasticity and increase the comfort of hemiplegic patients.¹⁴ Significant reduction in spasticity was observed, and muscle strength and the use of the upper limb in daily living were increased in distinct groups of muscle.

Temporary muscle paralysis with botulinum toxin seemed to be enough to trigger a change in the set point for muscle contraction in the central nervous system. Once the new set point was achieved, and with no apparent trigger for frontalis muscle contraction as in the preoperative status, it was noticed that patients stopped utilizing the muscle long after the effect of the toxin waned. Interestingly, there have been reports of patients with benign essential blepharospasm with remission of the disease after prolonged use of botulinum A toxin.¹⁵⁻¹⁸ Although the reason for resolution is unclear, benign essential blepharospasm patients should be informed that symptoms rarely abate after treatment with botulinum toxin; it may be that the toxin itself may influence the natural history of the disease, but this remains uncertain. Additionally, various investigators have noted an increased duration of botulinum toxin effect with larger doses in benign essential blepharospasm patients, which may be related to toxin-induced muscle atrophy¹⁹⁻²¹; however, these findings are inconsistent and controversial.²²

The drive for frontalis muscle contraction in our patients is intriguing and not well understood; this is demonstrated more clearly in the patient who presented with consecutive eyelid retraction after bilateral ptosis correction. Eyelid retraction may appear in unilateral ptosis patients as evidence of Hering's law of equal innervation, although the relatively autonomous contraction of orbicularis oculi inhibition of the frontalis may mask unilateral lid retraction. Frontalis muscle contraction follows this law, as demonstrated in brow ptosis patients.^{23,24} Our patient demonstrated frontalis muscle overactivity in an attempt to correct the contralateral eyelid ptosis; this was more apparent on the right side. Due to the long-standing nature of eyelid position, frontalis muscle contraction was inherent when even successful surgical correction of the retracted eyelid could not alleviate frontalis muscle action. This patient has continued using her frontalis muscle regardless of droopy or retracted eyelid position.

In summary, patients with long-standing eyelid ptosis who use the frontalis muscle as a compensatory mechanism to improve peripheral vision may continue to do so even after successful surgical correction with good eyelid position. Although some show spontaneous cessation of muscle contraction within months after surgery, resetting the point for muscle contraction and permanent motor relearning may be achieved by temporary chemodenervation with botulinum toxin. Once relearning has occurred, frontalis muscle function may return to the desired normal level for prolonged periods. The exact mechanism of this effect, however, remains unclear.

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