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Function of transected or avulsed rectus muscles following recovery using an anterior orbitotomy approach

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Abstract

PURPOSE—To assess the function of muscles retrieved from a retrobulbar location using an anterior orbitotomy approach and to identify the prognostic factors favoring a good outcome.

METHODS—The records of all patients undergoing anterior orbitotomy for the retrieval of a transected or avulsed muscle in a retrobulbar location were reviewed. Ocular motility, before and after retrieval (with ductions scaled from -4 to $+4$), was evaluated.

RESULTS—Record review identified 11 patients who had suffered trauma to 12 muscles (5 inferior, 6 medial, and 1 lateral rectus muscle). Ductions improved from -4 ± 0.4 preoperatively to -2.7 ± 0.9 postoperatively ($P = 0.002$); mean primary position deviation improved from $34^\Delta \pm 14^\Delta$ – $15^\Delta \pm 9^\Delta$ ($P < 0.001$), and mean deviation in the field of action improved from $47^\Delta \pm 20^\Delta$ – $20^\Delta \pm 22^\Delta$ ($P = 0.02$). Ductions improved by at least two units in three patients, all of whom had medial rectus trauma. Single binocular vision in primary gaze was achieved in 6 patients. Patients with medial rectus muscle injury and patients injured by sinus surgery had the lowest likelihood of recovering single binocular vision.

CONCLUSIONS—Our results are similar to historical series in which muscles were not retrieved and transpositions performed; however, muscle retrieval avoids risks associated with transposition surgeries such as anterior segment ischemia. Muscle recovery via the anterior orbitotomy approach may be reasonable to consider in those cases with a reasonable possibility of having active force generation postoperatively.

Extraocular muscle transection or avulsion is a grave complication of surgery or trauma. Various techniques for retrieval and repair of traumatized muscles have been described.^{1,2} In published series of rectus muscle disinsertion or transection, retrieval rates ranged from 50% to 100%.^{1–5} Muscles that are transected posteriorly are the most difficult to retrieve and are often impossible to retrieve from a standard anterior approach.^{1–5} In the largest study of traumatic muscle disinsertion, the retrieval rate was 53%, whereas the remaining 47% of cases were converted to adjacent rectus muscle transpositions or to maximal recessions of the antagonist muscle.⁴ Our group has used an anterior orbitotomy approach for retrieving transected rectus muscles, with a recovery rate of 100%.^{1,6}; however, because function of the retrieved muscle stump has not been systematically assessed, the utility of extensive surgical procedures remains questionable. The purpose of this study was to evaluate muscle function after retrobulbar recovery of severely traumatized rectus muscles via anterior orbitotomy.

Methods

This study was approved by the University of California, Los Angeles, Institutional Review Board and conformed to the requirements of the United States Health Insurance Portability and Accountability Act. Clinical records of all patients who underwent anterior orbitotomy combined with strabismus surgery between 1998 and 2010 were reviewed. Patients who sustained an extraocular muscle transection or insertional avulsion were included. Patients who suffered a ruptured globe or had undergone prior strabismus surgery were excluded. In general, patients underwent anterior orbitotomy and attempted retrieval in cases of severely traumatized rectus muscles whose anterior terminal portions were recognized to be in a retrobulbar location on magnetic resonance imaging (MRI) or computed tomography (Figure 1A and 1B) and displayed some evidence of contractile function on multipositional MRI performed at our center. In cases where multipositional MRI was not obtained, the mechanism and location of injury also became important in decision making: for example, in cases with very anterior avulsions. In general, if patients had a multipositional MRI that revealed a complete lack of contractility, we did not attempt to retrieve the rectus muscle after the acute phase of injury (<3 months). Our technique for visualizing extraocular muscle location and contractility using high-resolution surface-coil MRI to assess muscle thickening during contraction by imaging in different positions of gaze is described elsewhere.⁷⁻⁹

The following pre- and postoperative characteristics were assessed: time from injury to surgery, best-corrected visual acuity, preoperative motor alignment at distance in the cardinal positions of gaze, degrees of torticollis, and ocular ductions. Surgical data included the results of intraoperative forced duction testing and all subsequent surgical procedures. Forced duction testing of the antagonist muscle was typically scored on a four-point scale: no restriction, “mild” restriction (felt at approximately 10° of rotation), “moderate” restriction (felt at approximately 20° of rotation), and “severe” restriction (felt at approximately 30° of rotation).

In general, ocular alignment in most cases was measured using Krimsky light reflex testing due to poor motility; however, if motility improved postoperatively, alignment was occasionally assessed using cover-uncover and alternate prism cover testing at distance (20 feet) in the cardinal gaze positions. Motor alignment at near was assessed at 14 inches. All motor evaluations were done using spectacle correction. Torticollis was estimated in the patient’s habitual head position in degrees by the same clinician pre- and postoperatively, but no goniometer or other quantitative device was utilized. Ocular ductions were measured using a standard nine-point scale (–4 to 4).¹⁰ If the patient was unable to reach the midline, the ocular duction was recorded as “off-scale” and designated –5. All pre- and postoperative evaluations were done by the same strabismus surgeon (Arthur L. Rosenbaum), who was not masked to the procedure or history. Our procedure for recovering extraocular muscles using an anterior orbitotomy approach has been published.¹ In brief, the periosteum is accessed via a transconjunctival approach, and dissection proceeds posteriorly toward the orbital apex. Because the muscle belly is situated immediately adjacent to the periosteum in the posterior orbit, it is located easily and then advanced as far as possible with the globe rotated into a –1 contralateral rotation while minimizing restriction of globe rotation (evaluated by intraoperative forced duction testing).

Surgical outcome was analyzed in two ways. Objective success based on ductions was defined as at least two units of improvement in duction (eg, –4 improvement to –2). Subjective success was characterized by elimination of diplopia in the primary position.

Statistical analyses were performed using the statistical software STATA version 10.0 (StataCorp, College Station, TX). To assess parametric differences between pre- and

postoperative measurements, paired *t* test was used. To assess associations of continuous variables with success or failure status, a Mann-Whitney-Wilcoxon test was performed. The association of various preoperative factors and a successful outcome was determined using the Fisher exact test. A χ^2 test was used to compare groups for ordinal values (eg, results of forced duction testing). A *P* value of 0.05 was deemed statistically significant for all comparisons.

Results

A total of 11 patients were included, with the following underlying etiologies: two orbital fractures (both inferior rectus); three inadvertent entries into the orbit, with resultant muscle transection during endoscopic sinus surgery (all medial rectus); three cases of extraocular muscle “pulled in two syndrome” during extraocular surgery [scleral buckle in two patients (one medial rectus/inferior rectus, one lateral rectus), laser blepharoplasty in one patient (inferior rectus)]; and two other traumas [fish hook to eye in one patient (medial rectus), shattered glass to eye in one patient (inferior rectus)]. A representative patient is depicted in Figure 2. Both patients with orbital fracture and one who had endoscopic sinus surgery underwent orbital fracture repair, and four patients had undergone attempted muscle recovery prior to successful retrieval at our institution. One patient with muscle injury during scleral buckle surgery had “pulled in two syndrome” of both the medial and the inferior rectus muscles (Figure 2). Of the 11 patients, 9 underwent multipositional MRI scans at our institution, of which 7 were available for review. All of these MRI scans revealed contractility in the injured muscle [mechanisms of injury: fracture (*n* = 2), external trauma (*n* = 1), scleral buckle procedure (*n* = 1), sinus surgery (*n* = 3)]. The mean time from the injury to muscle retrieval was 10 ± 6 months (range, 0.5-18). Mean postoperative follow-up was 16 ± 19 (range, 6-52) months. The mean duction was -4 ± 0.4 (range, -5 to -3.5) in the field of action of the affected muscle and -0.8 ± 1 (range, -3.5 to 0) in the opposite field of action. The mean deviation at distance was $34^\Delta \pm 14^\Delta$ (range, $14^\Delta \pm 55^\Delta$) in the primary position, and $47^\Delta \pm 20^\Delta$ (range, 35^Δ - 80^Δ) in the field of the affected muscle. Comparisons to postoperative data can be found in Table 1. Overall, there was a significant improvement in duction in the field of action (≥ 2 units) of the affected muscle (*P* = 0.002), in the deviation in primary position (*P* < 0.001), and in the deviation in the field of action of the affected muscle (*P* = 0.02).

There were three subjects whose ductions improved objectively by at least two scale units. Of these, two had medial rectus trauma and one had inferior rectus trauma [one external trauma (medial rectus), two scleral buckle surgery (medial rectus and inferior rectus)]. Although several factors were analyzed to determine associations with an objective successful outcome (Table 2), the only statistically significant association with a successful outcome was a larger preoperative deviation in the primary position ($45^\Delta \pm 5^\Delta$ vs $30^\Delta \pm 14^\Delta$, *P* = 0.05) and less restriction on forced duction testing of the antagonist muscle (*P* = 0.05). For subjective success, six patients (55%) achieved single binocular vision in the primary position (Table 3). Statistically significant associations with a subjective successful outcome included injury to a rectus muscle other than the medial rectus (versus those cases with medial rectus injury) (*P* = 0.015), and injury other than sinus surgery (versus those cases with injury from sinus surgery) (*P* = 0.015). For a subjective successful outcome, there was no significant difference in the preoperative deviation of patients who had damage to the medial rectus muscle ($39^\Delta \pm 17^\Delta$) versus those with damage to other than medial rectus muscles ($29^\Delta \pm 8^\Delta$, *P* = 0.3). Two additional patients eventually achieved orthotropia in the primary position following additional antagonist recessions. In one case, the antagonist muscle was recessed alone, and in the other case, the retrieved muscle was advanced in combination with an antagonist recession. One subject who had no diplopia in primary gaze but a small primary position deviation (3^Δ) underwent a combined recession-resection

procedure on the affected inferior rectus muscle, which had a small effect on her primary position gaze, improving her alignment to orthotropia. One patient underwent recession of the antagonist muscle but did not achieve single binocular vision or orthotropic alignment. The remaining two patients did not achieve single binocular vision but did not undergo further surgical procedures.

Discussion

Extraocular muscle transection or avulsion is a rare complication of orbital trauma or extraocular surgery. Our approach to retrieving traumatized rectus muscle has been previously described.^{1,11} In 2001 our group reported the results of five patients who underwent rectus muscle retrieval after muscle transection or extirpation; however, we did not evaluate systematically whether there was statistically significant improvement in ductions and strabismus,¹ nor did we evaluate associations with successful outcomes. The current study assessed functional outcomes in 11 cases where an anterior orbitotomy approach successfully retrieved a posterior muscle stump.

Several authors have described series of patients with “lost” or “detached” rectus muscles, combining cases of severely traumatized muscles (such as those in our study) with muscles that had simply been lost or slipped after strabismus surgeries.³⁻⁵ In most of these series, several of the muscles could not be retrieved, but anterior orbitotomy was not utilized. In their series of “detached” rectus muscles, MacEwen and colleagues³ reported two traumatized muscles (one medial and one lateral rectus muscle), both of which were retrieved with “satisfactory” resultant function via a standard anterior approach. In a larger series, Plager and Parks⁵ reviewed a series of 25 cases of “lost muscles” over a 10-year period. The majority of the cases in their series were muscles that had been lost after strabismus surgery, but four patients were described who had muscle transections in association with trauma (one inferior rectus muscle) or extraocular surgery (one medial, two superior rectus muscles). Of these four cases, three muscles were retrieved via a standard anterior approach, and only one patient (33%) was orthophoric in the primary position postoperatively. Although their report focused mainly on the identification and management of “lost” muscles, a subsequent article by Wright¹² further elaborated on the management of these cases, suggesting early intervention within 7-10 days with advancement of the recovered muscle and simultaneous recession of the antagonist muscle if it is tight. Although we speculate that early intervention is best based on the potential to avoid contracture of the residual muscle stump or the antagonist muscle, several of our patients underwent muscle retrieval months after the initial injury and had successful recovery of single binocular vision (although improved ductions by 2 scale units was less common). We did not initially combine antagonist recessions in our cases, but 27% of the patients eventually underwent antagonist recession for residual deviations, which may have in part been due to an overestimation of the strength of the retrieved muscle stump or residual undercorrection despite rectus muscle recovery due to pulley tissue trauma or entrapment.¹³

In his 1998 Knapp lecture, Murray⁴ described a series of 25 patients who suffered traumatic muscle loss. Of these, 15 (60%) had successful rectus muscle recovery (7 inferior, 5 medial, 2 lateral, 1 superior rectus muscles) via a standard anterior approach, yet 17 (68%) were satisfactorily aligned and had a “functional field of binocular single vision.” Those patients whose muscles were not retrieved but had a successful outcome underwent transposition procedures with botulinum toxin chemodenervation to the antagonist muscle. Of the 15 cases of recovered muscles, 12 (80%) were considered successful, although the success criterion was not clearly defined.

Paradoxically, the patients in our series who were freed from diplopia in the primary position had larger preoperative deviations. Although we cannot explain this finding, we speculate that these patients might have had less coexistent restriction from the opposing muscle due to less extensive trauma. There was indeed a trend toward less restriction on intraoperative forced duction testing of the antagonist muscle in those patients who had more successful outcomes, and if patients had a more isolated injury, they might have had a larger primary position deviation than patients with more widespread orbitopathy restricting duction in all directions. Alternatively, the surgeons may have been more aggressive in advancing the muscle stump anteriorly after retrieval due to the knowledge of a large preoperative deviation.

Previous authors have suggested that outcomes are worse when the medial rectus muscle is disinserted because of the difficulty in retrieving the medial rectus due to its lack of attachment to an oblique muscle.^{4,5} Using the anterior orbitotomy approach, all six medial rectus muscles were retrieved; however, medial rectus trauma was associated with a less successful correction of diplopia. With this small case series, it is difficult to determine which of the significant associations are the true cause of the worse binocular function outcome, because the mechanism of injury (sinus surgery) and the muscle affected (medial rectus) in the patients with the worst outcomes are intimately associated.

Although there were several patients in our series with excellent subjective results after muscle retrieval, the improvement in duction was limited. Unfortunately we do not have a control group for this study consisting of patients treated with transposition procedures: all muscle retrievals were approached via anterior orbitotomy at our institution. However, in our experience, muscles that are entirely retrobulbar are not often successfully recovered from a standard anterior approach through Tenon's capsule.¹ The alternative to muscle retrieval is a transposition of the two adjacent rectus muscles to the scleral insertion of the injured muscle. Historical success rates of transposition for lost muscles are available. In Murray's series of patients with traumatic muscle loss, 17 muscles could not be retrieved. Of these cases, six underwent transposition, and five (83%) had "successful" outcomes.⁴ The Hummelsheim procedure was performed on 14 rectus muscles that could not be recovered by Plager and Parks,⁵ and 11 patients had a recession of the antagonist; 4 (29%) had duction improvement of 2 units in the field of action of the affected muscle, comparable to our rate of 22%. Although Plager and Parks did not comment on diplopia, six (43%) had postoperative deviations $<10^\Delta$, comparable to our single binocular vision rate of 44%. However, the advantage of rectus muscle recovery over rectus transposition is the decreased risk of anterior segment ischemia after surgery on two additional rectus muscles (in addition to the transected muscle) and perhaps a larger field of single binocular vision due to active force generation by the recovered rectus muscle. Our general recommendation is to attempt muscle retrieval if there is contractility apparent on multipositional MRI scan. If the muscle does not show contractile function on the MRI scan, an attempt at muscle retrieval can be made if the injury is still in the acute phase (<3 months) because the potential for recovery from nerve damage remains. After the acute phase of the injury, we believe that a lack of contractility most likely indicates nerve damage and probable poor rectus function after retrieval.

Results of this study must be understood within the context of its limitations. First, this study was retrospective and is therefore subject to inherent bias, including selection bias, changes in surgical technique, and referral bias. Furthermore, no control group was available, and we therefore cannot compare the results of our surgical technique directly to alternatives. Finally, because measurement of single binocular visual fields is not routinely tested in our clinics, we do not have data to analyze any changes in this parameter associated with rectus muscle retrieval.

Despite its limitations, this study provides an assessment of rectus function after retrieval via anterior orbitotomy in cases of severe extraocular muscle trauma that would have otherwise likely undergone rectus transposition. Our results are similar to historical series in which muscles were not retrieved and transpositions were performed. Given the availability of the anterior orbitotomy approach to retrieve rectus muscles, we believe that it is reasonable to attempt muscle recovery for the possibility of a larger field of single binocular vision due to active muscle contractility and decreased risk of anterior segment ischemia. To avoid undercorrections, consideration should be given to extra muscle advancement at the time of retrieval to counteract possible weakness in the injured muscle stump.

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FIG 1.

T1-weighted MRI scans of patients with muscle transections. A, Axial image of a patient with a medial rectus muscle (MR) transection deep in the orbit after endoscopic sinus surgery (arrow pointing to anterior portion of the transected muscle stump). B, Sagittal image of a patient with a traumatic inferior rectus (IR) muscle transection of the left eye (arrow pointing to anterior portion of the transected muscle stump). Residual contractility is revealed by contraction of the IR on downgaze (right panel) compared to relaxation on upgaze (left panel).

FIG 2. Clinical images in the primary position of a patient with left inferior and medial rectus transection during scleral buckle surgery. A, Preoperative appearance; B, Postoperative appearance after recovery of left inferior and medial rectus muscles.

Table 1

Pre- and postoperative characteristics of patients undergoing orbitotomy for retrieval of severely traumatized rectus muscles

	Preoperative (mean $\pm$ SD)	Postoperative (mean $\pm$ SD)	<i>P</i> value ^a
Torticollis, degrees	23 $\pm$ 8	13 $\pm$ 3	0.1
Ductions			
In field of affected muscle	-4 $\pm$ 0.4	-2.7 $\pm$ 0.9	0.002
In opposite field	-0.8 $\pm$ 1	-1 $\pm$ 1.6	0.5
Deviation, PD			
In the primary position	34 $\pm$ 14	15 $\pm$ 9	<0.001
In field of affected muscle	47 $\pm$ 20	20 $\pm$ 22	0.02

PD, prism diopters.

^aPaired *t* test.

Table 2

Associations with objective success (≥ 2 units improvement in ocular rotation) in patients undergoing orbitotomy for retrieval of severely traumatized rectus muscles

	Failure (n = 8)	Success (n = 3)	P value ^a
Time to surgery, months	10 $\pm$ 6	9 $\pm$ 8	0.8
Preoperative duction (mean $\pm$ SD)			
In field of affected muscle	-4 $\pm$ 0.4	-3.8 $\pm$ 0.4	0.09
In opposite field	-0.8 $\pm$ 1.2	-0.8 $\pm$ 1.1	0.46
Preoperative deviation in primary position, PD (mean $\pm$ SD)	30 $\pm$ 14	45 $\pm$ 5	0.05
Restriction on intraoperative forced duction testing of antagonist muscle	None/mild, 2 Moderate, 3 Severe, 3	None/mild, 3	0.05 ^b
Follow-up interval, months (mean $\pm$ SD)	18 $\pm$ 13	24 $\pm$ 25	0.36
MR involved (percentage)	4 (50)	2 (67)	1.0 ^c
Sinus surgery mechanism (percentage)	4 (50)	0	0.2 ^c

PD, prism diopters; MR, medial rectus muscle.

Numbers in parentheses indicate individual patient values.

^aWilcoxon test.

^b χ^2 test.

^cFisher exact test.

Table 3

Associations with subjective success (diplopia-free in the primary position) in patients undergoing orbitotomy for retrieval of severely traumatized rectus muscles

	Failure (n = 5)	Success ^a (n = 6)	P value ^a
Time to surgery (mean ± SD)	8 ± 6 months	12 ± 7 months	0.25
Preoperative duction (mean ± SD)			
In field of affected muscle	−4 ± 0.4	−3.8 ± 0.4	1.0
In opposite field	−0.8 ± 1.2	−0.8 ± 1.1	0.90
Preoperative deviation in primary position, PD (mean ± SD)	36 ± 18	33 ± 11	0.78
Restriction on intraoperative forced duction testing of antagonist muscle: number in each category	None/mild, 1 Moderate, 2 Severe, 2	None/mild, 4 Moderate, 1 Severe, 1	0.2 ^b
Follow-up interval, months	12 ± 6	26 ± 19	0.17
MR involved (percentage)	5 (100)	1 (17)	0.015 ^c
Sinus surgery (percentage)	4 (80)	0	0.015 ^c

PD, prism diopters; MR, medial rectus muscle.

^aWilcoxon test.

^b χ^2 test.

^cFisher exact test.