The Double-Bellied Inferior Oblique Muscle: Clinical Correlates

Dan D. DeAngelis, MD, FRCSC, and Stephen P. Kraft, MD, FRCSC

Purpose: We previously reported an 8% incidence of double-bellied inferior oblique (IO) muscles at the surgical capture site (10-12 mm from insertion) in cadaveric specimens. This companion study sought to determine how often this anomaly is encountered at surgery for clinically overacting IO muscles and whether clinical findings or surgical outcomes in cases with double-bellied muscles differ from those with single-bellied muscles. ***Methods:*** For 7 years we collected preoperative, intraoperative, and postoperative data on all patients for whom one surgeon performed primary IO weakening operations for overactions. We compared eyes with double-bellied IO muscles to those with single-bellied muscles on 4 variables—gradings of preoperative IO and superior oblique (SO) actions, presence of fundus excyclotropia, differences between horizontal deviations in upgaze and downgaze, and presence and sizes of primary position hypertropias—to determine whether one or more of them could predict the presence of a double-bellied muscle. Finally, we assessed postoperative IO actions to determine whether the presence of a double-bellied muscle influenced the effectiveness of IO weakening surgery in reducing overaction. ***Results:*** Among 162 patients (247 eyes) who underwent this surgery, 77 (77 eyes) had unilateral surgery and 85 (170 eyes) bilateral. Twenty-seven (10.9%) of the 247 muscles had double bellies. Among all variables compared, only the incidence of fundus excyclotropia differed significantly between groups, occurring more often in eyes with double-bellied IO muscles (48% vs 27%; $P = .041$). The efficacy of weakening surgery in reducing overactions was similar in both groups. ***Conclusion:*** The finding that eyes with double-bellied IO muscles showed a higher incidence of fundus excyclotropia suggests that the presence of a second belly may alter the physiologic action of the IO muscle. (J AAPOS 2001;5:76-81)

Anatomical studies show that anomalies are present in most ocular muscles, including the inferior oblique (IO) muscle,[1-6] and have documented the presence of multiple insertions of this muscle or of a duplicate or bifid IO muscle belly.[1-5] We previously reported an 8% incidence of bifid IO muscle bellies at the surgical "capture site" in cadaveric orbits of persons who, presumably, comprised a sample of a population free of eye-muscle problems.[7] The site was defined as the region 10 to 12 mm from the insertion where the muscle is retrieved during surgery. When correcting IO overaction, surgeons unfamiliar with this anatomic variation may unknowingly isolate only one belly of a double-bellied muscle and leave a portion of the other behind. This can result in persistent postoperative IO muscle overaction.

From the Department of Ophthalmology, The Hospital for Sick Children, and the University of Toronto, Toronto, Ontario, Canada.
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Corresponding author: Stephen P. Kraft, MD, The Hospital For Sick Children, Room 4112, 555 University Avenue, Toronto ON Canada, M5G 1X8 (e-mail: stephen.kraft@sickkids.on.ca).

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It is not known whether an overacting bifid IO muscle acts differently from one with a single belly. Similarly, factors that may allow a surgeon to predict if an overacting IO is likely to have a bifid structure have not been investigated. Predictive factors would alert the surgeon to take special care to look for multiple muscle bellies.

The purposes of this study were 3-fold: (1) To determine the incidence of multiple bellies of the IO muscle in surgically treated cases of IO overaction and compare this incidence with that derived from our earlier anatomic study of a nonstrabismic population. (2) To compare preoperative clinical data of patients with IO muscles with duplicate bellies to those of patients who had single-bellied muscles to see whether any clinical variables correlated with the presence of a double-bellied IO muscle. (3) To determine whether the response to weakening surgery is the same in IO muscles with multiple bellies as in those with single bellies.

SUBJECTS AND METHODS

All patients for whom one surgeon (S.P.K.) performed primary IO weakening operations to treat muscle overactions from January 1990 to December 1996 were entered into this prospective study. Each patient had undergone a full ocular motility examination by the same surgeon within 4 weeks before surgery. The examination included the following: (1) best corrected visual acuities for adults and verbal children or the binocular fixation pattern for preverbal children; (2) measurement of alignment in prism diopters (PD) with prism and cover test (or Krimsky test in young children) in at least the primary and 4 secondary gaze positions (rightward, leftward, upward, downward) and on forced head tilts; (3) grading of oblique muscle actions on a scale of +1 to +4 for overactions and –1 to –4 for underactions, with zero being normal;[8,9] and (4) determination of the presence of excyclotropia on funduscopy based on the relative positions of the foveolar light reflex and the inferior optic disc rim.[10-12]

All patients underwent IO weakening procedures, either unilateral or bilateral, including myectomy of 10 mm,[13] recession of 10 mm,[13] or anterior transposition to a point immediately lateral to the inferior rectus muscle.[14,15] Patients were included if they underwent surgery on any of the other extraocular muscles either at the same time as the IO weakenings or on a previous occasion. In all cases, the IO muscle was isolated as described by Parks,[13] and the approach was generally via a lower fornix incision. When surgery was performed on the lateral rectus muscle at the same time as the IO muscle, a temporal limbal incision was used. The surgeon always wore a headlamp to optimize visibility. The muscle belly was isolated by lifting and retracting the tissues in the lower quadrant and looking for the inferior-temporal vortex vein. Any duplications in the muscle belly were noted. The muscle was captured with a tenotomy hook under direct visualization and brought into the surgical field, and the quadrant was searched for remaining muscle tissue. After the desired surgery on the muscle was completed, the quadrant was inspected once more for residual muscle bellies or portions of muscle tissue.

A muscle was classified as bifid if we noted 1 of 2 findings: (1) the 2 heads could be clearly seen on initial isolation of the IO muscle, with the bellies clearly separated so that each appeared to have its own glistening muscle sheath (Figure); or (2) after surgery on the main portion of muscle, a residual belly with its own muscle sheath was found on reinspection of the lower quadrant. We followed the 2 bellies to the insertion on sclera to see whether the entire insertion was duplicated or whether the muscle had a duplication at the capture site but the bellies merged into a single head at the insertion. Both forms of duplication had been found in our cadaver study.[7] We tried to avoid including muscles that might have been iatrogenically split during the hooking of the IO belly. Specifically, we did not classify as bifid any muscles captured in 2 parts in which there was bleeding within the belly during capture or where muscle surfaces of one or the other portion were raw after capture. We submitted for histologic examination the 2 bellies of 4 IO muscles encountered at surgery and classified as bifid by our criteria. These specimens were stained with hematoxylin and eosin and examined by light microscopy.

In all cases the minimum follow-up period after surgery was 6 months. At the last examination the patients underwent a full ocular motility examination that included gradings of the muscle actions, with special care taken to grade the IO and superior oblique (SO) muscles.

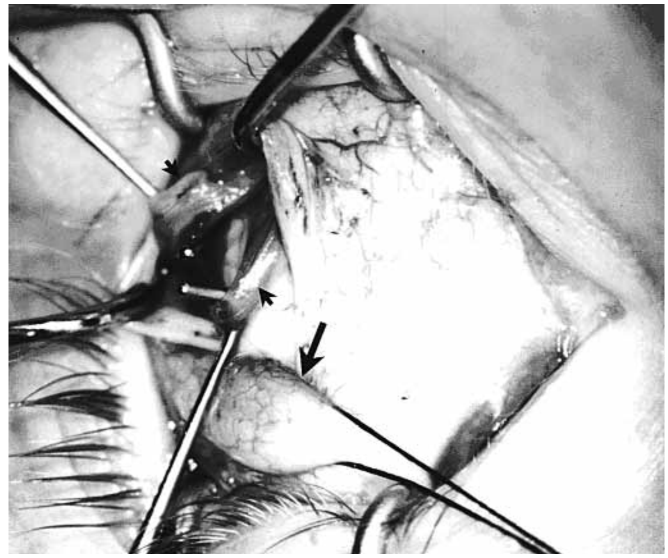

FIGURE. Surgeon's view of double-bellied inferior oblique muscle in a left eye. A silk suture around the lateral rectus muscle *(large arrow)* is retracting the globe upward and medially. Tenotomy hooks are lifting and pulling apart a smaller anterior belly and a larger posterior belly *(small arrows)*. Note intact glistening muscle sheaths around each belly.

We compared the eyes with double- and single-bellied IO muscles on several clinical variables, as follows: (1) gradings of preoperative IO and SO muscle actions, (2) presence or absence of fundus excyclotropia, (3) magnitude of preoperative horizontal deviations in upgaze versus downgaze, (4) presence of V patterns (defined as a minimum 15 PD difference between these values), (5) sizes of preoperative primary position hypertropias, and (6) gradings of most recent postoperative IO and (SO) muscle actions.

The first 2 variables were compared for all eyes in the study. Upgaze versus downgaze deviations were analyzed separately for the unilateral and bilateral cases because the size of the pattern in a given case is influenced by the presence of IO overaction in 1 or 2 eyes. Among the bilateral surgery cases, we compared data for the 3 patients with bifid muscles in both eyes with those of 72 patients with single-bellied muscles in both eyes. The analysis of primary position hypertropias was carried out only for the 77 unilateral surgery cases. Finally, comparing the postoperative oblique actions of the double- and single-bellied muscles allowed us to determine whether the presence of a bifid IO muscle influenced the efficacy of a weakening procedure in reducing overactions. By far the most frequent procedure performed was a 10-mm myectomy, done on 195 eyes and yielding the largest body of data for analysis. Statistical comparisons for this last parameter were performed between the subgroups of patients with bifid and single-bellied muscles who underwent this procedure.

TABLE 1. Anatomic data on all patients undergoing IO muscle–weakening surgery

Surgery category	Muscle structure	No. of patients	No. of muscles	No. with 2 bellies
Unilateral	Single belly	66	66	0
	Double belly	11	11	11
Group total		77	77	11
Bilateral	Single bellies in both eyes	72	144	0
	1 double and 1 single belly	10	20	10
	Double bellies in both eyes	3	6	6
Group total		85	170	16
Total, both groups		162	247	27

TABLE 2. Comparison of preoperative oblique muscle action gradings and presence of fundus excyclotropia in IO muscles with single and double bellies

Variable	Double-bellied muscles	Single-bellied muscles	*P* value (χ^2)
No. of eyes	27	220	
IO action (mean ± SD)	+2.5 ± 0.6	+2.5 ± 0.7	.48
SO action (mean ± SD)	–0.6 ± 0.7	–0.6 ± 0.8	.29
No. with excyclotropia (%)	13 (48.1)	60 (27.2)	.041

The χ^2 test was used to correlate the presence or absence of a duplicate IO muscle to the following preoperative variables: IO and SO muscle action grading, presence of excyclotropia, and presence of a V pattern. The test was also used in the subgroup analysis (of myectomies) to correlate postoperative oblique muscle gradings to the presence of single- or double-bellied IO muscles. An unpaired *t* test of differences between means was used to compare the eyes with single IO bellies to those with double bellies, the differences in horizontal deviation in upgaze versus downgaze between the 2 groups, and the size of the hypertropias in these groups. *P* values under .05 were considered significant.

RESULTS

A total of 247 eyes (muscles) of 162 patients were included in the study. The ages of patients at the time of surgery ranged from 13 months to 66 years. Follow-up intervals after surgery ranged from 6 to 36 months, with a mean of 7.5 months. A total of 77 patients (77 muscles) underwent unilateral IO weakening surgery and 85 patients (170 muscles) underwent bilateral surgery. At surgery, 27 (10.9%) of the IO muscles were found to have 2 bellies at the capture site, including 24 that also had duplicate insertions to sclera and 3 whose bellies rejoined into a single insertion. Twenty-four (14.8%) of the patients were found to have at least 1 bifid muscle. Detailed findings on the IO muscles are presented in Table 1.

TABLE 3. Comparison of V patterns and sizes of upgaze/downgaze differences in IO muscles with single and double bellies

Variable	Double-bellied muscles	Single-bellied muscles	*P* value
Unilateral surgery			
No. of patients	11	66	
No. with V patterns (%)	3 (27.3)	6 (9.1)	.11†
Mean size (PD) ± SD	10.6 ± 1.3	12.0 ± 2.5	.41‡
Range (PD)	10–12	10–15	
Bilateral surgery*			
No. of patients	3	72	
No. with V patterns (%)	2 (66.7)	53 (73.6)	.19†
Mean size (PD) ± SD	12.0 ± 1.6	13.4 ± 5.0	.70‡
Range (PD)	10–14	10–15	

*Data included only for patients with bilateral bifid or bilateral single-bellied muscles.
†As calculated by χ^2 test.
‡As calculated by unpaired *t* test

Histologic examination of the 4 pairs of muscle specimens from the myectomized muscles showed separate bellies for the 2 portions in each case. Each belly was invested with its own muscle sheath, confirming the clinical impression at time of surgery that the IO muscle was bifid and had not been iatrogenically split.

All 247 eyes were included in the analyses of preoperative oblique muscle gradings and fundus excyclotropia (Table 2). The mean preoperative gradings of the IO and SO muscle actions did not differ significantly between the eyes with double-bellied IO muscles and those with single-bellied muscles. Among the 27 eyes with bifid muscles, 13 (48%) had excyclotropia noted before surgery compared with 60 (27%) of 220 eyes with single-bellied muscles. This difference was statistically significant (P = .041). Excyclotropia was noted in 11 of the 24 eyes having bifid muscles with duplicate insertions compared with 2 of the 3 eyes having muscles with single insertions.

The results of comparison of bifid and single-bellied muscles on the 2 variables, size of horizontal deviations in upgaze versus downgaze positions and presence of V patterns, are shown in Table 3. Among the 77 patients who had unilateral surgery, there was a higher incidence of V patterns in the 11 with bifid muscles than in the 66 with single-bellied muscles, but the small size of the first group prevented the difference from achieving statistical significance. Mean sizes of the upgaze versus downgaze horizontal deviations were similar in both groups. Among the bilateral surgery cases, the analysis was limited by the small number of cases (n = 3) of bilaterally bifid muscles. Mean sizes of the upgaze versus downgaze differences were similar in both groups.

We analyzed data on primary position hypertropias for the 77 patients who had unilateral surgery (Table 4). Mean sizes of the deviations were almost identical in the 2 groups.

Our analysis of oblique muscle actions included 195 eyes in patients who underwent IO myectomies: 19 had

TABLE 4. Comparison of preoperative primary position hypertropias in IO muscles with single and double bellies for unilateral surgery cases

Variable	Double-bellied muscles	Single-bellied muscles	*P* value (unpaired *t* test)
No. of patients	11	66	
Mean size (PD) ± SD	13.4 ± 4.4	13.1 ± 6.5	.88
Range (PD)	6–20	2–35	

TABLE 5. Comparison of preoperative and postoperative IO and SO actions in muscles with single and double bellies for patients who underwent IO myectomies

Variable	Double-bellied muscles	Single-bellied muscles	*P* value (χ^2)
No. of eyes	19	176	
Preoperative data*			
IO grading	+2.7 ± 0.7	+2.6 ± 0.6	.60
SO grading	–0.9 ± 0.7	–0.7 ± 0.8	.62
Postoperative data			
IO grading	–0.1 ± 0.8	0.0 ± 0.6	.55
SO grading	0.3 ± 0.5	0.0 ± 0.3	.046

*Values represent mean ± SD.

bifid muscles, 176 had single-bellied muscles (Table 5). Mean gradings of IO muscle actions, both preoperative and postoperative, were similar in both muscle groups, as earlier noted for preoperative data for the total patient group (Table 2). Mean grades of preoperative SO actions were also similar in both groups. The mean postoperative SO grade in the bifid group was slightly on the underaction side, whereas the mean grade in the single-bellied group was zero, or normal action. The difference between the 2 SO muscle groups in postoperative mean grades, although barely significant (P = .046), does not appear to be of clinical significance.

DISCUSSION

Knowledge of the anatomy of the IO muscle, including unusual alterations in its structure, is crucial to performing a safe, successful operation. One relatively little-known variation in the muscle's anatomy is the duplication of its muscle belly.[7] Failure to recognize and deal with the presence of a second belly can lead to failure of a weakening procedure or complicate a planned transposition of this muscle.

Before 1984, descriptions of duplicated IO bellies were limited to isolated case reports.[2-6] In 1984, Emmel et al[1] published their large, systematic cadaver study describing single and multiple insertions of the IO. They found several IO muscles with 2 bellies, suggesting that this was not a rare anatomic finding. However, they restricted their observations to the insertion of the muscle. Because this is not the site of "capture" of the muscle at time of surgery, we thought it was important to conduct a new cadaveric study to define the anatomic variations at the capture site, defined as lying 10 to 12 mm from the insertion.[7] Our study found that the duplication of the IO belly at this site manifested either as a "split" (or dehiscence) that created 2 bellies for several millimeters near the insertional end of the muscle, or as 2 distinct bellies inserted separately into the sclera. We found an 8% incidence of duplication of the belly among cadaver eyes from a normal population with no history of strabismus.

In contrast, to our knowledge, nothing has yet been published about the incidence of double-bellied IO muscles among eyes with overactions requiring surgical correction. To obtain this information, we collected data prospectively on the IO anatomy at the capture site for all patients who underwent weakening surgery for overaction, at the same time as we performed the anatomic study. We anticipated that the incidence of this anatomic variation among overacting muscles would be higher than that in the normal population. We also wanted to determine if any clinical measurements in the preoperative evaluation of these patients could predict the presence of a bifid IO belly. If one or more factors were highly correlated with the presence of a duplicate belly, eye surgeons would be forewarned to look for this variation at the time of surgery.

Our data analysis showed that among 247 overacting IO muscles there were 27 with double bellies at the capture site, representing an incidence of 10.9%, a figure only marginally higher than the 8% in normal orbits reported in our earlier study. This difference may indicate that a double-bellied IO muscle has a slightly higher propensity to overact than a single-bellied one. These data can also be interpreted to suggest that there is a stable incidence of duplicate IO muscle bellies of 8% to 10% in the general population and that an eye with this finding is not at increased risk of developing overaction.

Only the preoperative finding of fundus excyclotropia showed a significant correlation with a bifid IO muscle at surgery. Excyclotropia was noted in eyes with bifid muscles that had duplicate insertions, as well as in eyes whose bifid muscles had single insertions. Fundus excyclotropia is an important clinical sign in the evaluation of oblique muscle problems in both adults and children.[10,11] In fact, the detection of excyclotropia in eyes of infants with congenital strabismus is highly correlated with later development of IO overaction, even if the oblique muscle actions are normal at first assessment.[12] Our results suggest that the excyclotropic action of the IO muscle may be enhanced by the presence of 2 bellies. The 2 bellies, by virtue of their slightly different muscle paths along the globe, may serve different functions, perhaps one predominantly responsible for excyclotropia and the other for the vertical action. Perhaps an altered torsion vector of the anterior portion of the muscle could exaggerate its excyclotropic action. Because we did not quantify the degree of excyclotropia in the fundi, we cannot comment on the relative severity of torsion in the eyes with bifid versus nonbifid IO muscles.

Anatomic segmentation of cyclotropic action within an oblique muscle is not a new concept. Previous work on the division of labor within the SO tendon showed that its anterior fibers are more responsible for its cyclotropic action than the posterior part of the tendon.[16,17] This principle forms the basis for the Harada-Ito transposition and its variations, which are surgical procedures designed to improve the incyclotropic action of a weak SO muscle without disturbing its vertical action.[18]

Less well known is that weakening the anterior portion of the IO muscle has been reported to weaken its excyclotropic action without affecting vertical action.[17,19] This supports the premise that even in an IO with a single belly the actions of its anterior and posterior fibers may differ. This division of labor may be even more striking in a bifid muscle, in which the anterior fibers have an exaggerated torsion action. Our data suggest, however, that the vertical action of bifid IO muscle is not enhanced, since no differences were noted in mean vertical tropias or degree of IO overactions when eyes with single-bellied muscles were compared with bifid IO muscles. In addition, presence of a double belly does not seem to enhance the abducting force of the IO muscle: we found no difference in size of horizontal deviations between upgaze and downgaze in comparing eyes with single-bellied IO muscles with those with double-bellied IO muscles.

It could be argued that some of the IO muscles we classified as bifid were, in fact, single-bellied muscles inadvertently split during capture of the muscle and its dissection. However, we took special care during surgery to avoid making this error. First, we performed all our operations with the use of magnifying loupes and by following the method described by Parks,[13] including head-mounted illumination to enhance the visibility of the tissues in the surgical field. Second, most of the bifid bellies were observed to be duplicated as soon as the soft tissues in the inferior temporal quadrant were retracted to expose the muscle and before it was actually hooked to bring it into the surgical field. Observation of the double-bellied muscle was confirmed at the same time by the assistant surgeon. Third, in classifying an IO muscle as bifid we stipulated that the 2 bellies had to be invested by separate muscle sheaths. In most eyes, the 2 bellies could be pried apart without traumatizing the muscle fibers and inducing bleeding. In the rest of the eyes with bifid IO muscles, the second belly was found on inspection of the quadrant after we had operated on the first one. Just as we stipulated for the clearly bifid bellies, this second portion had to have an intact sheath around the belly's circumference to be labelled a belly rather than a fragment of an iatrogenically-split single belly. Fourth, if any bleeding occurred during separation of 2 segments of an IO muscle or any blood was seen around a second fragment when it was isolated, we did not assign these muscles to the bifid category.

Furthermore, to support our clinical judgment that we could identify separate bellies in these cases, we sent for histologic study the myectomy specimens of 4 IO muscles classified at surgery as having bifid bellies and taken from 4 different patients. These specimens included both the main and secondary bellies. In each case our impressions were confirmed. All 8 bellies were invested with their own sheaths. Thus, we felt confident that we could identify duplicate bellies at surgery by following our criteria.

We did not subject our muscle specimens to electron microscopic study because we were primarily interested in detecting the presence of sheaths of the separate bellies. Studies by Mukuno et al[20] and by Meyer et al[21] showed ultrastructural changes in muscle fibers in overacting IO muscles, including mitochondrial aggregates and muscle vacuolation in the IO myofibrils.

Our data from eyes that underwent myectomies suggest that weakening surgery on the IO muscle is equally effective in reducing overaction for muscles with single and double bellies. This finding should not be surprising because the success of IO weakening surgery depends on weakening the entire muscle bulk. If no portion of muscle is left in situ, then its anatomic configuration should be about the same at the conclusion of surgery, whether 1 or 2 bellies were present at the capture site. This point underscores the importance of inspecting the inferior temporal quadrant for residual muscle tissue when it appears at first that a single belly is present. The small number of recessions and anterior transpositions we performed did not allow separate analyses of the efficacies of these 2 weakening procedures in reducing IO overactions in duplicate versus single-bellied muscles.

In summary, we found an incidence of 10.9% of double-bellied IO muscles at the surgical capture site among eyes undergoing weakening surgery. A duplicate IO muscle may have an altered division of labor that enhances the excycloro-tatory function of its torsion fibers, which may predominate in the anterior belly. A surgeon who notes the presence of excyclotropia of the fundus in an eye with an overacting IO muscle should search carefully at surgery for a bifid structure. However, the absence of excyclotropia does not rule out the presence of a bifid muscle: there were no pathognomonic signs that could predict this anatomic finding. Thus, any surgery on the IO muscle demands careful examination to be sure all portions of the muscle are dealt with, whether there are one or more bellies. Isolation of the entire muscle bulk during surgery appears to lead to a successful outcome irrespective of the number of bellies encountered.

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An Eye on the Arts – The Arts on the Eye

... and she gave me a wary look—from a pair of black eyes set close to a hawk nose. Such eyes, known as Gypsy or witches' eyes, could bring crippling illness, plague, or death. That is why she forbade me to look directly into her eyes or even those of the household animals. She ordered me to spit quickly three times and cross myself if I ever accidentally looked into an animal's eyes or her own.

—Jerzy Kosinski (from *The Painted Bird* p 7)