Clinical findings and surgical outcomes of patients with traumatic isolated inferior rectus muscle paresis

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PURPOSE To evaluate clinical findings and surgical outcomes of patients with traumatic isolated inferior rectus muscle paresis.

METHODS The medical records of patients with traumatic isolated inferior rectus paresis who underwent strabismus surgery at Farabi Eye Hospital between 2011 and 2018 were reviewed retrospectively. Clinical features, type of surgery, and surgical outcomes were extracted from the record for analysis.

RESULTS A total of 19 patients (14 males [74%]) were included. Mean patient age was 34.8 ± 14.6 years. Left eyes in 13 patients (68%) were involved. Thirteen cases (68%) underwent orbital reconstruction surgery for blow-out fracture. Preoperative limitation of duction in the gaze of the inferior rectus muscle was −2 to −3 in all cases. Four patients (21%) had a paradoxical contralateral compensatory head tilt. Inferior rectus muscle resection alone was the first surgical intervention in 12 patients (63%). At the final follow-up, 12 patients (63%) were orthotropic, without any deviation or diplopia in primary position and downgaze. Three patients (16%) had a residual hypertropia of 3^{Δ} at distance and near without diplopia, and 4 patients (21%) required reoperation.

CONCLUSIONS In our patients with traumatic isolated inferior rectus paresis with persistent deviation at least 6 months after trauma, a stepwise approach based on size of the vertical deviation was employed, with good outcomes: inferior rectus resection alone for hypertropia of 6^{Δ}-20^{Δ} and inferior rectus resection and superior rectus recession for hypertropia of $\geq 20^{\Delta}$ or significant hypertropia in the field of the superior rectus muscle. (J AAPOS 2019;23:315.e1-5)

Isolated inferior rectus muscle paresis is a relatively rare entity.[1] Different etiologies have been described, including trauma, myasthenia gravis, congenital absence of the inferior rectus muscle, nuclear third nerve palsy, vascular abnormalities, iatrogenic, and idiopathic.[2] However, orbital trauma, with or without an associated orbital wall fracture, is the most commonly reported etiology. Direct muscle damage and nerve injury were suggested as possible mechanisms.[3] Although several studies describe clinical features of isolated inferior rectus paresis,[1-3] to our knowledge, traumatic isolated inferior rectus muscle paresis has not been investigated exclusively. The purpose of this study was to report the clinical characteristics and surgical outcomes of 19 patients with traumatic isolated inferior rectus paresis.

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Submitted September 7, 2018.
Revision accepted August 2, 2019.
Published online October 15, 2019.
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1091-8531/$36.00
https://doi.org/10.1016/j.jaapos.2019.07.008

Subjects and Methods

This study was approved by the ethical committee of Farabi Eye Research Center. All aspects of this investigation were consistent with the principles of the Declaration of Helsinki. All interventions were performed with informed consent. The medical records of 19 consecutive patients with traumatic isolated inferior rectus paresis who underwent surgery at the strabismus clinic of the Farabi Eye Hospital between 2011 and 2018 were reviewed retrospectively. Cases of traumatic isolated inferior rectus paresis without improvement at least 6 months after trauma and constant deviation lasting at least 4 months were included. Patients who had paresis or underaction of other extraocular muscles, a history of strabismus surgery, positive forced duction testing to elevation or depression, elevation limitation, evidence of fat entrapment, or significant scarring in orbital computed tomography (CT), and patients who did not return for follow-up examination were excluded.

The angle of deviation was measured by prism and alternate cover test with the prism placed in the front of paretic eye.

Near (33 cm) and distance (6 m) deviations were measured separately. Additionally, the amount of deviation in 9 positions of gaze was determined. The measurements in head tilt positions were performed with about 30° head tilt to each side (estimated by an experienced observer). The limitation of duction in inferior rectus muscle gaze was assessed on a scale of 0 to −4, with 0 representing no limitation and −4 representing no movement beyond the midline.[4] The difference between horizontal deviations in up- and downgazes was calculated to evaluate the presence of A and V patterns. A significant pattern was defined as A pattern of $>10^{\Delta}$ and V pattern of $>15^{\Delta}$. Subjective torsion in primary position was measured by double Maddox rod testing. All measurements were performed by an orthoptist before and after surgery and confirmed by a strabismologist. The orthoptist and strabismologist's measurements showed $<5^{\Delta}$ difference in all cases. When the data were different, the strabismologist measurements were used for analysis.

Force generation for the inferior rectus muscle was performed for all cases. The results of this test were classified as normal, weak, or absent.[5] If the examiner could not rotate the globe against muscle force in the opposite direction, the result was classified as normal. If the examiner rotated the globe and felt resistance, the result was classified as weak. If the globe could be rotated without resistance, the result was classified as absent. Grading of the severity of the infraduction deficit and force generation were used to distinguish between inferior rectus paresis and complete inferior rectus palsy.

Isolated inferior rectus muscle paresis was diagnosed based on the maximum hypertropia in depression and abduction, and inferior rectus muscle underaction in duction testing. Contralateral superior oblique overaction and skew deviation, which can mimic inferior rectus paresis, were excluded by comparing ductions of the sound and paralyzed eye and lack of other neurologic signs, respectively.[1,3]

Orbital CT scans were performed for diagnosis of blow-out fractures and to rule out residual entrapment after blow-out fracture surgery. Because reliable software was lacking, no muscle measurement was performed. If CT showed significant scarring or evidence of fat entrapment, the patients were excluded from the study. Hess screen testing was performed to evaluate limitations and rule out residual entrapment or, for example, superior oblique paresis.

Significant vertical deviation in primary position or downgaze, diplopia in primary position or downgaze, and significant head posture were indications for surgery. Forced duction testing for all vertical muscles was performed intraoperatively under general anesthesia for all patients. All surgeries were performed by two authors (MRA, AM). Limbal conjunctival incision and scleral fixation sutures with 6-0 polyglactin 910 were used in all surgeries, which were performed according to the method described by Coats and Olitsky.[6]

We defined surgical success as vertical deviation of $<4^{\Delta}$ and absence of diplopia in primary position and downgaze at final follow-up. Postoperative visits occurred at 1 day, 1 week, 1 month, and 3 months after surgery and thereafter as needed. At each time point, the presence of diplopia in primary position and downgaze was evaluated, and ocular deviations were measured. All statistical analysis was performed with SPSS version 24 (SPSS Inc, Chicago, IL).

Table 1. Baseline characteristics of patients with traumatic inferior rectus muscle paresis[a]

Variable	Result
Age, years	34.8 ± 14.6 (6-57)
Male/female	14 (73.6)/5 (26.4)
Left eye involvement	13 (68.4)
History of orbital reconstruction surgery	13 (68.4)
Pre-op primary position HT (distance), PD	14.9 ± 7.6 (0-35)
Pre-op primary position HT (near), PD	14.0 ± 7.0 (0-25)
Pre-op downgaze HT, PD	19.9 ± 7.6 (6-35)
Pre-op HT in field of IR muscle action, PD	22.6 ± 8.7 (7-35)
Pre-op primary position horizontal deviation	
XT	8 (42.1)
ET	6 (31.5)
No horizontal deviation	5 (26.3)
Mean pre-op XT in exotropic cases, PD	8.9 ± 4.7 (3.5-18)
Mean pre-op ET in esotropic cases, PD	6.66 ± 3.01 (2-10)
Difference of deviation in right and left head tilt, PD	6.9 ± 6.1 (1-20)

ET, esotropia; *HT*, hypertropia; *IR*, inferior rectus; *PD*, prism diopter; *SD*, standard deviation; XT, exotropia.
[a]Categorical data are given as number (percent); quantitative data, as mean ± SD (range).

Results

A total of 19 patients with traumatic isolated inferior rectus muscle paresis were included in this study. In all cases, visual acuity was at least 20/80 in each eye. Baseline patient characteristics are given in Table 1. The 2 cases with minimal or no primary position and significant downgaze hypertropia before surgery (Table 1) had larger hypertropia at the first visit after trauma. With time, partial recovery occurred. Thus, the hypertropia in primary position improved, but hypertropia in downgaze remained. Both cases had a history of orbital reconstruction for blow-out fracture.

Preoperative limitation of duction in the gaze of the inferior rectus muscle was −2 to −3 in all cases, and in all cases there was some force in the inferior rectus muscle on force generation testing. Thus, all patients were in the category of weak force generation and were diagnosed with inferior rectus paresis rather than complete palsy. Our surgical approach in cases with −2 and −3 limitations did not differ from the general approach. None of the patients had significant A or V pattern.

Three patients (16%) had only ipsilateral compensatory head tilt. Two patients (11%) had ipsilateral head tilt with ipsilateral head turn. Four patients (21%) had only contralateral compensatory head tilt. In these cases, the amount of deviation in ipsilateral head tilt was more than contralateral head tilt. Three of 4 cases with contralateral head tilt had history of blow-out fracture surgery. There was no significant difference in far and near primary position hypertropia and limitation in the gaze of inferior rectus muscle between the cases with contralateral head tilt and other

Table 2. Indications for each type of surgery and number of cases that underwent each type

Type of first surgery	Indication	No. patients (%)
IR resect	Primary position HT 6-20 PD, HT in field of IR $\leq$30 PD, and small-angle HT in field of SR	14 (73.6)
IR resect and SR recess	Primary position HT $\geq$20 PD or significant HT in field of SR	2 (10.5)
IR resect and contra IR recess	Primary position HT 15-20 PD, HT in field of IR >30 PD	1 (5.2)
Contra IR recess and posterior fixation suture	Primary position HT $\leq$5 PD, significant HT and diplopia in downgaze	1 (5.2)
Contra IR posterior fixation suture	Primary position orthotropia, significant HT and diplopia in downgaze	1 (5.2)

Contra, contralateral; *HT*, hypertropia; *IR*, inferior rectus muscle; *Recess*, recession; *Resect*, resection; *SR*, superior rectus muscle.

cases ($P = 0.88$ for distance deviation; $P = 0.66$ for near deviation; $P = 1.0$ for limitations). No chin-down posture was found in our cases. Ten patients (53%) had no abnormal head posture. The subjective torsion was measured in 2 patients (11%). The measured intorsion was 4° in one patient and 5° in the other. There was no evidence of fat entrapment in the included cases on orbital CT.

The indications of each type of surgery and number of cases that underwent each type are provided in Table 2. Forced duction testing for all vertical muscles was negative. No flap tear or other abnormality was found in the inferior rectus muscles intraoperatively. The mean muscle resection in patients who underwent only inferior rectus resection was 4.1 ± 0.6 mm (range, 3–5 mm). The posterior fixation sutures were placed at the distance of 15 mm from limbus. No pulley fixation suture was used.

Postoperative Outcomes

The mean follow-up of our patients was 8.5 ± 4.4 months (range, 3-20). At the final follow-up after initial surgery, 11 patients (58%) were orthotropic, without any deviation and diplopia in primary position, downgaze, and upgaze. At 1 week, 1 of these patients (5%), had a little overcorrection (hypotropia in the affected eye), in the range of 2^{Δ}-3^{Δ}, which later resolved. Three patients (16%) had residual hypertropia of 3^{Δ} at distance and near without diplopia, which remained constant during the follow-up period.

Four patients (21%) required reoperation. All 4 cases underwent inferior rectus resection in the first surgery. Of the 4, 2 underwent contralateral inferior rectus posterior fixation suture in the second surgery, 1 underwent contralateral inferior rectus muscle recession, and 1 underwent contralateral inferior rectus recession with posterior fixation suture. The deviation and diplopia resolved in all 4 cases with reoperation. Thus, the success rate was 79% after primary surgery and 100% at final follow-up.

Some comparisons were made between patients that underwent only inferior rectus resection and those who underwent inferior rectus resection and superior rectus recession (vertical recession and resection). The mean distance and near deviation in the vertical recession-resection group was significantly higher than inferior rectus resection group (distance deviation, $30.0^{\Delta} \pm 7.1^{\Delta}$ in the vertical recession-resection group vs $14.3^{\Delta} \pm 3.9^{\Delta}$ in the inferior rectus resection group [$P = 0.000$]; near deviation, $25.0^{\Delta} \pm 0.0^{\Delta}$ vs $14.2^{\Delta} \pm 4.2^{\Delta}$ [$P = 0.004$]). The mean limitation of duction in the gaze of inferior rectus muscle was not significantly different between the two groups (−2.3 ± 0.5 in the inferior rectus resection group vs −2.5 ± 0.7 in the vertical recession-resection group [$P = 0.71$]). The rate of reoperation was not significantly different between groups (4/14 in the inferior rectus resection group vs 0/2 in the vertical recession-resection group [$P = 0.77$]).

In patients who underwent only inferior rectus muscle resection, the mean dose–response (amount of vertical deviation improvement in primary position with each millimeter of resection) was $3.0^{\Delta} \pm 1.0^{\Delta}$ (range, 1^{Δ}-4.2^{Δ}) for distance and $3.0^{\Delta} \pm 1.1^{\Delta}$ (range, 1.1^{Δ}-4.5^{Δ}) for near. In the inferior rectus resection group, there was no significant difference for distance and near dose–response between the patients with −2 and −3 limitations (distance, $3.16^{\Delta} \pm 1.3^{\Delta}$ for −2 and $2.94^{\Delta} \pm 1.0^{\Delta}$ for −3 [$P = 0.74$]; near, $3.00^{\Delta} \pm 1.3^{\Delta}$ for −2 and $3.1^{\Delta} \pm 1.2^{\Delta}$ for −3 [$P = 0.87$]). In the patients who underwent vertical recession-resection, the mean dose–response (amount of vertical deviation improvement in the primary position with each millimeter of resection plus recession) was $2.7^{\Delta} \pm 0.3^{\Delta}$ (range, 2.5^{Δ}-2.9^{Δ}) for distance and $2.2^{\Delta} \pm 0.3^{\Delta}$ (range, 2^{Δ}-2.5^{Δ}) for near.

Discussion

In this study, the clinical characteristics and surgical outcomes of 19 patients with traumatic isolated inferior rectus paresis were evaluated. To our knowledge, traumatic isolated inferior rectus paresis has not previously been studied in isolation, and few studies have addressed it in the context of different etiologies.

Mauriello and colleagues[7] studied 16 patients with blowout fracture and found that the most commonly involved extraocular muscle following trauma was isolated involvement of the inferior rectus muscle. Furthermore, trauma, including blow-out fracture, is the most common etiology of isolated inferior rectus paresis.[3]

In our previous study of 22 cases (12 traumatic) with isolated unilateral inferior rectus paresis, 3 patients required reoperation.[2] The success rate in that study on all etiologies of inferior rectus paresis (86%) was similar to that of the present study (78.9%), suggesting that traumatic etiology may have no effect on surgical success. Choie and colleagues[8] studied 44 patients with acquired isolated inferior rectus palsy and found that blow-out fracture reconstruction and strabismus surgery resulted in improvement in 7 of 12 patients (58%) with traumatic origin. Von Noorden and Hansell[1] reported 21 cases (7 traumatic) with isolated inferior rectus palsy. Fourteen patients were cured, 6 improved, and 1 patient's deviation was unchanged postoperatively.

The left eye was involved more frequently (68%) than the right eye in our study, which is consistent with similar studies. The mean primary position hypertropia of 14.9^{Δ} at distance and 14.0^{Δ} at near was lower than in other studies.[1,3] These results supported previous experiences about lower vertical deviation in the traumatic inferior rectus palsy.[2] Mean hypertropia in the field of action of the inferior rectus muscle in our study did not differ significantly from that of other studies. In contrast with previous studies, significant A or V pattern was not seen in our patient cohort, which may be because of different pattern definition in other studies.[2]

As in previous studies,[1,3] we found both ipsilateral and contralateral compensatory head tilt in our patients, in contrast with the expected ipsilateral head tilt in inferior rectus paresis, according to the classic Bielschowsky head-tilt test. These findings suggest that head tilt test is not an accurate clinical test in the diagnosis of inferior rectus paresis.

Von Noorden and Hansell[1] concluded that simultaneous recession and resection was more effective in reducing hypertropia. In our study, the number of cases improved only by inferior rectus resection was considerable (53%), and only 2 patients (11%) required vertical recession-resection versus 61.9% in the von Noorden and Hansell study[1]; however, they reported a much higher average preoperative vertical deviation (19^{Δ}) than ours (14^{Δ}). We recommend a stepwise approach based on the size of the vertical deviation: inferior rectus resection for lower hypertropia and vertical recession-resection for higher hypertropia.

With regard to the 2 cases with minimal or no primary position and significant downgaze hypertropia before surgery, these patients had larger hypertropia at the first visit after trauma. With time, they recovered partially. Thus, the primary position hypertropia improved but downgaze hypertropia remained. Another explanation for these cases is that the presence of mild inferior rectus restriction that decreased the primary position hypertropia. Although all cases with positive forced duction testing and elevation limitation were excluded from our study, some mild cases of inferior rectus restriction may have been missed.

Pirouzian and colleagues[9] reported 5 cases of infraduction limitation and restriction due to scar formation after lower eyelid surgery. The term *reverse hypertropia* is appropriate in this situation and may explain downgaze hypertropia in our 2 cases. However, in contrast with Pirouzian and colleagues,[10] forced duction testing to depression was negative in our cases and the possibility of reverse hypertropia was low.

In our study, in the patients who underwent vertical recession-resection, each millimeter of resection plus recession caused approximately 2.5^{Δ}-2.9^{Δ} correction of hypertropia, similar to the published surgical dose tables. In the tables, each millimeter of the inferior rectus resection plus superior rectus recession corrected 2.5^{Δ}-2.7^{Δ} of hypertropia.[10] This finding may be useful for similar operations.

The main limitations of this study were its retrospective design and inability to diagnose direct trauma to the inferior rectus versus trauma to the connective tissue. Other limitations are the small number of patients (because of the relative rareness of traumatic isolated inferior rectus paresis), performing multiple procedures in some cases, lack of an exact mechanism to ensure the same head tilt position for all measurements, clinical rather than radiological confirmation of the palsy, lack of reliable CT scan software to calculate muscle cross-section, the possibility of missing mild cases of inferior rectus restriction, the possibility of missing reverse hypertropia with entrapment, and combining mild paresis with more severe paresis. Moreover, only patients who underwent surgery were investigated: we could not describe the clinical features of cases that resolved spontaneously. We suggest multicentric prospective studies with larger sample sizes to further evaluate the different aspects of this infrequently occurring entity.

Literature Search

We conducted a systematic search in PubMed, Scopus, and Embase after 1970 using the following terms: *inferior rectus palsy*, *inferior rectus paresis*, *blow-out fracture*, and *orbital wall fracture*.

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