Original Article

Outcomes and Dose-Response Ratio of Surgery on Three Muscles in Large-Angle Exotropia

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Abstract

Purpose: To evaluate the efficacy of three-muscle surgery for the treatment of large-angle exotropia with particular attention to the success rate and mean dose-response ratio.

Methods: In a retrospective study, medical records were reviewed for 48 patients with exodeviation between 50 and 80 prism diopter (PD) who underwent bilateral lateral rectus recession as well as one medial rectus resection. Sex, age at surgery, presence of amblyopia, amount of preoperative and postoperative deviation, total amount of recessed and resected muscles, dose-response ratio, and associated vertical deviations were analyzed.

Results: The mean age of patients at surgery was 25.4 ± 14.3 years old (range, 1–55). The mean preoperative deviation was measured 62.8 ± 7.5 PD (range, 50–80 PD). The mean amount of total recession and resection was 23 ± 1.3 mm. After a mean follow-up of 15 ± 25 months (range, 3–144), 85.4% of patients were within 10 PD of orthophoria. The mean postoperative deviation decreased to 3.8 ± 7.5 PD (range, 0–30 PD). A mean dose-response ratio of 2.5 ± 0.3 PD/mm (range, 0.9–3.1 PD/mm) was found. Of all patients, 14.6% demonstrated undercorrection.

Conclusion: Simultaneous surgery on three muscles is an effective method in resolving large-angle exotropia and results in excellent outcomes with low risk of undercorrection.

Keywords: Dose-response ratio, Large-angle exotropia, Three-muscle surgery

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Introduction

Although two-muscle surgery has been generally accepted for exodeviation <50 prism diopter (PD),[1] surgeons encounter less agreement in terms of the number and amount of operated extraocular rectus muscles when deviation exceeds 50 PD. While some surgeons continue to use two-muscle surgery, but include maximal or supramaximal doses,[2-4] others add augmentations such as Botox injections to recessed muscles[5,6] and central tenectomy[7] to enhance the effect of the recession. The disadvantages of these approaches include lower success rates and lateral incomitance.

Another option is the simultaneous operation on three muscles (bilateral lateral rectus recession and unilateral medial rectus resection).[8] The main issue in the application of three-muscle surgery is a lack of standard guidelines and recommended surgical dosage. There have been only a few studies regarding three-muscle surgery for large-angle exotropia. In this study, we report the results of one-stage surgery on three muscles for large-angle exotropia and calculate the dose-response ratio.

Methods

In this retrospective study, we reviewed the medical records of all subjects identified with large-angle exotropia who underwent three-muscle surgery between 2011 and 2017 at the strabismus

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clinic of Nikookari Eye Center a tertiary eye care center in Tabriz, Iran. This study was conducted in compliance with the guidelines of the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the Tabriz University of Medical Sciences with ethics approval code of 92.1-6.9. Patients with exotropia were included if the amount of deviation was between 50 and 80 PD at a distance. Those with a previous history of extraocular muscle surgery, paralytic or restrictive strabismus, neurological disease, or <3 months of follow-up were excluded. Informed consent was obtained from all patients or their parents if they were minors.

A complete ophthalmological examination was performed on all patients. Motor assessment in cooperative and attentive patients was done with the prism and alternate cover test using single loose prisms at 6 m and 33 cm with an accommodative target while patients had corrective glasses on eyes. The 50 PD prism was placed in front of one eye, and another of increasing power was placed before the other eye. Corrective tables[9] were then used to calculate the result of adding two prisms together. In uncooperative patients or those with poor visual acuity, deviation was assessed using the Krimsky test. The distance deviation was used for statistical purposes. Amblyopia was defined as a difference of ≥2 lines between two eyes. In children unable to cooperate for the Snellen chart, fixation pattern was used for the detection of amblyopia. A child was considered amblyopic if they always fixated with one eye or could not preserve fixation with the other eye for more than 5 s. Mild amblyopia is classified as being visual acuity of 20/25–20/40, moderate amblyopia as being worse than 20/40–20/100, and severe amblyopia as being worse than 20/100.

Parameters that were analyzed included gender, age at surgery time, presence of amblyopia, amount of deviation in PD in the last preoperative visit and the last follow-up after operation, total amount of recessed or resected muscles in millimeters (mm), dose-response ratio, symptomatic lateral incomitance (defined as diplopia in the lateral gaze), and associated deviations such as inferior oblique overaction (IOOA), superior oblique overaction (SOOA), and dissociated vertical deviation (DVD).

One surgeon (R.N.) performed all operations under general anesthesia, and the other author measured all pre and postoperative deviations. After a standard limbal incision, both lateral rectus muscles were recessed, and the medial rectus was resected in the non-dominant eye. Table 1 shows the surgical dose used for surgery. All measurements for muscle recession were taken from muscle insertion. Two single-armed absorbable 6-0 Vicryl (Polyglactin 910; Ethicon, Livingston, United Kingdom) were used to suture muscles to the sclera. The conjunctiva was closed with single-armed absorbable 8-0 Vicryl (Polyglactin 910; Ethicon, Livingston, United Kingdom). Patients who were within 10 PD of orthophoria at least 3 months after surgery were considered to show successful results.

Table 1: Surgical dose

Amount of deviation (PD)	BLR recession (mm)	MR resection (mm)
50-60	8-8.5	5
61-65	9	5.5
66-70	9.5	5-5.5
71-80	10	6

BLR: Bilateral lateral rectus, MR: Medial rectus, PD: Prism diopter

Statistical analysis was performed with SPSS 22.0 for Windows (IBM, Inc., Chicago, IL, USA). $P < 0.05$ were considered statistically significant. Categorical variables were reported using frequency and percentage, and numerical variables were described as mean with standard deviation. Chi-square test, paired *t*-test, and Wilcoxon test were used for the analytical evaluation.

Results

A total of 48 patients (28 males; 20 females) were included in this study. Demographic data and the pre and postoperative characteristics of the subjects are summarized in Table 2. The mean age at operation time was 25.4 ± 14.3 years old (range, 1–55 years old). The overall mean preoperative deviation was 62.8 ± 7.5 PD (range, 50–80 PD). Visual acuity could not be examined in 5 patients because of young age. In the rest of them, the mean best corrected visual acuity was 0.08 ± 0.15 logMAR units (range, 0–0.9 logMAR units) in the dominant eye and 0.13 ± 0.09 logMAR units (range, 0–1.1 logMAR units) in the non-dominant eye. The mean spherical equivalent of the dominant eye was −0.83 ± 0.05 D (range, +2.0 to −3.5 D) and -1.05 ± 0.11 D (range, +2.0 to −4.0 D) in the non-dominant eye. Twelve subjects (25%) showed amblyopia. Associated clinical findings showed pure DVD in three patients, IOOA in eighteen, DVD/IOOA in three, and SOOA in two patients. Simultaneous inferior oblique weakening surgery was performed on five patients with a significant V pattern. The average time of patients' follow-up was 15 ± 25 months (range, 3–144 months). The mean amount of bilateral lateral rectus recession was 8.6 ± 0.5 mm (range, 8–10 mm), and the mean resected unilateral medial rectus was 5.7 ± 0.4 mm (range, 5–6 mm). The mean amount of all recessed and resected muscles was 23 ± 1.3 mm. The overall mean distance angle of postoperative deviation at the last follow-up was 3.8 ± 7.5 PD (range, −8 – 30 PD, while negative notation shows esotropia).

Regarding the total amount of recession or resection (23 mm) and the total corrected amount of deviation (59 PD), the mean dose-response ratio was determined to be 2.5 ± 0.3 PD/mm (range, 0.9–3.1 PD/mm). The goal of 10 PD of orthophoria was seen in 41 patients (85.4%). None of the patients had diplopia in the lateral gaze in the last follow-up visit. All seven patients who were considered to have unsuccessful results showed residual exotropia. The mean age of the undercorrected group was 24.5 ± 40.6 years old, and the preoperative deviation was 62.6 ± 5.9 PD (range, 50–69 PD). Statistically, there was no significant difference between the successful group and the undercorrected group in terms of age ($P = 0.07$) and preoperative deviation ($P = 1$). Two were amblyopic.

Table 2: Demographic data and the pre and postoperative characteristics of the patients

Case	Sex	Age (years)	Amblyopia	Associated deviation	Preoperative angle of deviation (PD)	Postoperative angle of deviation (PD)	Total amount of BLR recession and MR resection (mm)	Dose-response ratio (mm/PD)	Follow-up (months)
1	Male	3	No	DVD	63	Ortho	23.5	2.86	144
2	Male	15	No	IOOA	69	Ortho	24.5	2.88	3
3	Male	30	No	No	55	Ortho	21	2.62	12
4	Male	15	No	No	75	Ortho	26	2.88	3
5	Female	4	No	No	63	14-XT	23.5	2.33	3
6	Male	30	No	IOOA	75	Ortho	26	3	66
7	Female	1	No	DVD	69	Ortho	24.5	3	80
8	Male	45	Yes	IOOA	78	Ortho	26	3	6
9	Female	22	No	IOOA	66	20-XT	24.5	1.92	39
10	Male	34	Yes	No	55	4-XT	21	2.43	7
11	Female	6	Yes	IOOA	63	18-XT	23.5	2.05	58
12	Male	23	No	No	69	10-XT	24.5	2.46	3
13	Male	34	No	No	50	Ortho	21	2.38	3
14	Male	40	No	No	63	Ortho	23.5	2.63	3
15	Female	15	Yes	IOOA	63	Ortho	23.5	2.74	3
16	Male	27	No	No	63	Ortho	23.5	2.74	6
17	Female	25	No	No	63	8-XT	23.5	2.39	4
18	Female	15	No	No	78	4-XT	26	2.73	12
19	Male	37	Yes	No	50	30-XT	21	0.91	3
20	Female	38	No	SOOA	63	8-ET	23.5	3.09	32
21	Female	18	No	DVD, IOOA	50	2-XT	21	2.29	15
22	Male	3	Yes	IOOA	63	Ortho	23.5	2.74	10
23	Male	44	No	No	75	Ortho	26	3.13	6
24	Male	26	No	IOOA	69	12-XT	24.5	2.38	21
25	Male	26	No	No	63	Ortho	23.5	2.74	16
26	Male	7	No	SOOA	66	Ortho	24	2.87	14
27	Female	47	Yes	IOOA	55	Ortho	22	2.5	10
28	Male	20	No	No	50	Ortho	22	2.27	3
29	Male	37	Yes	IOOA	50	4-XT	22	2.09	6
30	Female	55	No	DVD, IOOA	66	Ortho	24	2.75	9
31	Male	26	Yes	IOOA	66	6-XT	24	2.5	10
32	Male	22	No	DVD, IOOA	55	Ortho	21	2.74	6
33	Female	2	No	No	50	Ortho	21	2.27	9
34	Female	53	No	No	55	6-ET	21	2.77	6
35	Male	3	No	No	69	Ortho	24.5	2.88	3
36	Female	32	No	No	50	Ortho	21	2.38	4
37	Male	47	Yes	IOOA	66	Ortho	24	2.75	4
38	Male	25	No	No	55	Ortho	21	2.74	4
39	Female	13	No	IOOA	69	Ortho	24	2.88	4
40	Male	26	No	No	55	8-XT	21	2.24	3
41	Male	39	No	No	55	10-XT	21	2.67	4
42	Female	22	No	DVD	66	Ortho	24	2.75	7
43	Male	31	No	IOOA	63	25-XT	23.5	1.65	17
44	Female	46	No	IOOA	66	14-XT	24	2.17	6
45	Male	11	No	IOOA	55	Ortho	21	2.5	16
46	Female	18	No	IOOA	66	8-XT	24.5	2.42	8
47	Female	33	Yes	IOOA	69	Ortho	24.5	2.88	6
48	Female	30	Yes	No	63	Ortho	23.5	2.74	6

PD: Prism diopter, BLR: Bilateral lateral rectus, MR: Medial rectus, DVD: Dissociated vertical deviation, IOOA: Inferior oblique overaction, Orto: Orthophoria, XT: Exotropia, ET: Esotropia

Five had associated IOOA. Four were unhappy with results and subsequently underwent medial rectus resection on the dominant eye as a secondary operation and reached orthotropia following the secondary operation.

Discussion

The study evaluated the outcome of single-stage three-muscle surgery in patients with more than 50 PD of exotropia. The high success rate of 85.4% at the mean follow-up time of 15 months in the present study demonstrates that strabismus surgeons can opt to perform simultaneous surgery on three muscles in large-angle exotropia. The unsuccessful group (14.6%) showed undercorrection. In the study by Tibrewal *et al*.,[10] amblyopia was not as associated with a higher failure rate. In the present study, the dose-response ratio was 2.5 PD/mm when the bilateral rectus was simultaneously recessed with the medial rectus resection in large-angle exotropia.

Although two-muscle surgery, including bilateral rectus muscle recession or unilateral lateral rectus recession and medial rectus resection, has advantages such as less surgery time and a lower number of operated muscles, reported success rates for large-angle exotropia are relatively low. In a study by Livir-Rallatos *et al*.,[11] the results were reported for bilateral lateral rectus recession in 52 patients and unilateral recess/resect procedure in 11 patients with deviations between 35 and 125 PD. The amount of bilateral rectus recession ranged between 8 and 15 mm, and in cases with unilateral surgeries, the lateral rectus was recessed between 8 and 12 mm, and the medial rectus was resected between 4 and 7 mm. The overall success rate was 62%; however, two-muscle surgery was successful in only 18% of patients with deviations larger than 50 PD. Celebi and Kükner[2] reported a success rate of 76% after the bilateral rectus recession between 8.0 and 9.5 mm. Deviations exceeding 65 PD were not included in their study, and they considered 15 PD a successful result, as opposed to the current study, which considered a success as 10 PD of orthophoria. Recently, ElKamshoushy[12] launched a study to investigate the effect of bilateral medial rectus resection for exotropia between 60 and 140 PD. The medial rectus was resected, ranging between 8 and 12 mm. Their study showed 77% of their patients had a successful outcome, and the success rate was equal in both the smaller and larger angles of deviation. However, after 6 months of follow-up, 36% of their patients showed some degree of limitation on abduction.

There are limited studies regarding the outcomes of three-muscle surgery in large-angle exotropia.

Our results are comparable to a similar study conducted by Lau *et al*.[8] which reported the outcome of three-muscle surgery in 24 patients with mean preoperative exotropia of 71.3 PD after a mean follow-up of 15.8 months. They concluded that a success rate in deviations of < 80 PD (84.2%) was higher in comparison with deviations of ≥ 80 PD (40.0%). Moreover, the probability of success in subjects with intermittent exotropia was higher than that seen in the constant exotropia group. No cases of significant limitation of the ocular movement were seen at the last follow-up. They did not calculate a dose-response ratio. The reported success rate of 100% by Cifuentes *et al*.[13] is higher than this study, but they included only six patients with deviations of ≥ 50 PD. Surgeries were performed on adjustable sutures, and this might be the cause of immediate full success. One patient had induced lateral incomitance, and it was not defined to which group of exotropia it belonged. Yang *et al*.[14] compared the results of two-muscle surgery on 25 patients with intermittent exotropia of 60–70 PD with the results of three-muscle surgery done on 15 patients with intermittent exotropia of >70 PD. The overall success rate was reported as 77.5%, and there were no statistically significant differences in success rates between the two- and three-muscle surgery groups. Li and Zhang[15] studied the effect of three horizontal muscle surgery for exotropia with angles ≥120 D, where 10–15 mm of lateral rectus recession was done on the dominant eye in addition to 9–13 mm of lateral rectus recession and 6.5–9 mm of medial rectus resection on the non-dominant eye. Eighty-three percent of subjects were successfully aligned after a mean follow-up of 8 months. In their study, some abduction limitation was observed, but none of the patients were symptomatic. The effect of three- or four-muscle surgery for deviations exceeding 40 PD was evaluated by Chen *et al*.,[16] who operated on three muscles in 34 patients with mean preoperative exotropia of 55 PD. They also performed four-muscle surgery in 13 patients with a mean exotropia of 72 PD. After 2 months of follow-up, success rates of 67% and 44% were reported, respectively. At the final follow-up, the success rate was reported as 42% for the three-muscle group and 50% for the four-muscle group.

The limitations of this study include its retrospective method, differing and relatively short follow-up periods, and the absence of comparison with other surgical techniques. In addition, different types of exotropia were not categorized. Nevertheless, the success rate of 85.4% in this study suggests that three-muscle surgery can be considered an effective procedure for improving large-angle exotropia. It has a negligible risk for overcorrection and low risk for undercorrection and reoperation. Furthermore, a calculated dose-response ratio of 2.5 PD for every mm of recession or resection in patients undergoing three-muscle surgery for exotropia can be used as a guide for future surgeries. We recommend further prospective studies, particularly interventional clinical trials with more participants and larger amounts of deviation, which will add to the knowledge base for adjusting the surgical formula.

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Conflicts of interest

There are no conflicts of interest.

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