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# One- vs two-muscle surgery for presumed unilateral fourth nerve palsy associated with moderate angle hyperdeviations

**David L. Nash**[1,2], **Sarah R. Hatt**[1], **David A. Leske**[1], **Laura May**[3], **Erick D. Bothun**[1,3], **Brian G. Mohney**[1], **Michael C. Brodsky**[1,4], and **Jonathan M. Holmes**[1]

[1]Department of Ophthalmology, Mayo Clinic, Rochester, Minnesota

[2]Department of Ophthalmology, Gundersen Health System, La Crosse, Wisconsin

[3]Department of Ophthalmology and Visual Neurosciences, University of Minnesota, Minneapolis, Minnesota

[4]Department of Neurology, Mayo Clinic, Rochester, Minnesota

## Abstract

**Purpose—**To compare one-muscle versus two-muscle surgery for moderate-angle hyperdeviations due to presumed unilateral fourth nerve palsy.

**Design—**Retrospective chart review

**Methods—**73 patients (5 to 86 years) underwent either one- or two-muscle surgery at our institution, for moderate hyperdeviation, due to presumed unilateral fourth nerve palsy, measuring 14 to 25 PD in straight ahead gaze at distance fixation. Six week and 1-year motor success was defined as zero vertical deviation or 1–4 PD undercorrection at distance, overcorrection as any reversal of hypertropia, and undercorrection as >4 PD. Diplopia success was defined as no diplopia, or only rarely for distance straight ahead and reading.

**Results—**28 patients underwent one-muscle surgery, and 45 patients underwent two-muscle surgery. Motor success was similar (64% vs 67%, P>0.99 at 6 weeks; 47% vs 55%, P=0.8 at 1 year, n=46), but there were more undercorrections at 6-weeks with one-muscle surgery (36% vs 16%, p=0.09), and more overcorrections at 6-weeks with two-muscle surgery (0% vs 18%, p=0.02). Diplopia success was also somewhat similar between one- and two-muscle surgery at 6 weeks (73% vs 60%, p=0.5) and 1 year (45% vs 59%, P=0.5).

**Conclusion—**For moderate angle hyperdeviations due to presumed unilateral fourth nerve palsy, there appears no clear advantage of two-muscle surgery for motor outcomes. Diplopia success at was similar between one- and two-muscle surgery, due to a greater number of less symptomatic

**Correspondence and reprint requests to**: Dr. Jonathan M. Holmes, Ophthalmology W7, Mayo Clinic, Rochester, MN 55905, Phone: (507) 284-3760, Fax: (507) 284-8566, holmes.jonathan@mayo.edu.



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undercorrections with one-muscle surgery, and a smaller number of more symptomatic overcorrections with two-muscle surgery.

## Introduction

The surgical management of hyperdeviation due to unilateral fourth nerve palsy is controversial. Many surgeons base the choice of surgical procedure on the magnitude of the hyperdeviation in primary position, preferring a single muscle procedure for deviations measuring less than 15 prism diopters (PD),[1–3] and a two muscle procedure for deviations greater than 20 PD.[4] Nevertheless, single muscle surgery has been performed on primary position hyperdeviations up to 37 PD,[5–8] and two-muscle surgery on primary position hyperdeviations less than 20 PD.[8, 9] We are unaware of previous studies that have compared one-versus two-muscle surgical approaches where either approach might be reasonable, specifically for moderate-angle hyperdeviation (14–25 PD). The aim of the present study was to compare motor and diplopia outcomes in patients undergoing one versus two muscle surgery for moderate-angle hyperdeviation due to presumed unilateral fourth nerve palsy.

## Methods

Institutional review board approval was obtained from the Institutional Review Boards at Mayo Clinic, Rochester, Minnesota, USA and University of Minnesota, Minneapolis, Minnesota, USA. All procedures and data collection were conducted in a manner compliant with the Health Insurance Portability and Accountability Act, and all research procedures adhered to the tenets of the Declaration of Helsinki.

### Patients

We retrospectively reviewed the medical records of patients aged 5 years and older, undergoing strabismus surgery at our institution, on either one or two vertical rectus or oblique muscles, for moderate angle hyperdeviation due to presumed unilateral fourth nerve palsy. A minimum age of 5 years was chosen to allow assessment of diplopia as one of the outcome measures.

Patients were identified from departmental databases. We included both presumed congenital and acquired fourth nerve palsy that had been present for at least 6 months and had not undergone previous strabismus surgery. We included patients who had moderate hyperdeviation, defined as 14 to 25 PD by prism and alternate cover test (PACT) at distance fixation, and at least 10 PD hyperdeviation at near fixation. Patients with developmental delay, coexisting dissociated vertical deviation, Graves' ophthalmopathy, third or sixth cranial nerve palsies, myasthenia gravis, nystagmus, or supranuclear disorders were excluded. Patients with suspected bilateral fourth nerve palsy (for example more than 15 degrees of excyclotropia) at the preoperative examination were also excluded since we were primarily interested in the correction of hyperdeviation and not torsion.

### Surgery

We included any type of oblique or vertical rectus muscle surgery aimed at correcting the vertical deviation in primary position. We excluded patients undergoing a Harada-Ito procedure since this is performed primarily to address torsion. Surgery using adjustable and non-adjustable sutures was allowed, and for patients undergoing two-muscle surgery we allowed both unilateral and bilateral procedures. The choice of surgical procedure was based on a number of factors including degree of incommitance, and magnitude of vertical deviation in lateral gaze positions, as well as surgeon's preference. Nevertheless, since the specific reasons for performing one surgery over another were not explicitly stated in the medical record, we were unable to evaluate any possible selection bias. We excluded patients if horizontal rectus muscle surgery was performed simultaneously. All surgeries were performed by one of the authors (JMH n=42, EDB n=15, BGM n=12, MCB n=4).

## Clinical Examinations

Six-week postoperative examinations (target window 3 weeks to <5 months following surgery, actual range 3 to 17 weeks, median 7 weeks) were required for inclusion in the study, selecting the examination closest to 6 weeks. We also identified 1-year postoperative examinations where available (target window 5 to 24 months following surgery, actual range 6 to 23 months, median 12 months). From both preoperative and postoperative examinations data were recorded on angle of deviation measured by PACT at distance (3 meters or 6 meters) and near (1/3 meter) in the straight ahead distance. Torsion was measured at near using double Maddox rods. If torsion data or near angle PACT were not recorded at the preoperative exam, data were taken from the nearest adjacent examination, within 6 months.

From the 6-week and 1-year postoperative examinations, we extracted data regarding diplopia frequency for straight ahead distance and reading positions. For some patients, diplopia had been formally assessed using the Diplopia Questionnaire,[10] providing a patient-reported rating of diplopia as present either "never," "rarely," "sometimes," "often," or "always" in specific positions of gaze. For patients who had not completed the Diplopia Questionnaire, assessment of diplopia frequency was based on the history recorded in the medical record.

## Statistical Analysis

Patients were classified according to whether they underwent one-muscle or two-muscle surgery for hyperdeviation. Mean preoperative vertical angle of deviation at distance was compared between one-muscle or two-muscle groups.

At 6 weeks and 1 year postoperatively, patients were classified as achieving motor success or not achieving motor success. Motor success was defined as zero hyperdeviation or 1 to 4 PD of undercorrected hyperdeviation at distance fixation by PACT. Patients not achieving motor success were classified as overcorrected if there was 1 PD or more reversal of the hyperdeviation at distance by PACT, and undercorrected if there was >4 PD of residual hyperdeviation at distance by PACT. If reoperation occurred before the 1-year examination we assigned a 1-year outcome of motor failure (no patients underwent reoperation before the 6-week outcome). For these patients assigned motor failure for the 1-year outcome, we classified as overcorrected or undercorrected based on alignment at the preoperative examination (i.e., immediately prior to reoperation). The rate of motor success and the rates of undercorrection and overcorrection were compared between patients undergoing one-muscle versus two-muscle surgery using Fisher exact tests for 2×2 tables. Motor outcome analyses were repeated for the sub-group of patients who had 1-year examinations (in addition to 6-week examinations), recalculating diplopia success at 6 weeks and 1 year.

Patients were also classified as achieving or not achieving diplopia success at the 6-week and 1-year postoperative examinations. Diplopia success was defined as diplopia present "never" or only "rarely" for both straight ahead distance and for reading, without any prism correction, as described previously.[11] Partial diplopia success was defined as diplopia present no more than "sometimes" for either straight ahead distance or for reading, in prism correction if prescribed, and diplopia failure was defined as diplopia present more than "sometimes" for either straight ahead distance or for reading, as described previously.[11] For a subset of patients, we were unable to obtain any data regarding diplopia frequency, and these patients were not included in analysis of diplopia success. The rate of diplopia success at 6 weeks was compared between patients undergoing one-muscle versus two-muscle surgery using Fisher exact tests. The rate of diplopia success was also compared between undercorrected motor failures and overcorrected motor failures. Diplopia outcome analyses were repeated for the subgroup of patients with 1-year examinations (in addition to 6-week examinations), recalculating success at 6 weeks and 1 year. If reoperation occurred before the 1-year examination, we assigned a 1-year outcome of diplopia failure.

In secondary analyses we compared 6-week and 1-year motor and diplopia success rates in patients undergoing inferior oblique weakening only and those undergoing inferior oblique weakening combined with contralateral inferior rectus weakening (the most commonly performed one-muscle and two-muscle procedures).

## Results

### Patients

Seventy-three patients were included of whom 40 (55%) were male. Median age was 42 (range 5 to 86) years. The majority 51 (70%) were presumed congenital unilateral fourth nerve palsy. Thirteen (18%) had a known history of acquired fourth nerve palsy due to head trauma (9) or neurosurgery (4). For 9 (12%) the cause was unspecified. All 73 had 6-week outcome examinations and 46 (63%) also had 1-year outcomes.

### Surgical procedures

Twenty-eight patients (38%) underwent one-muscle surgery, and 45 (62%) two-muscle surgery (Table 1). Median preoperative angle of hyperdeviation was somewhat smaller in patients undergoing one-muscle surgery (16 PD) than in patients undergoing two-muscle surgery (19 PD, difference −2.1, 95% CI −3.8 to −0.4, P=0.02). Of the 28 undergoing one-muscle surgery, 15 (54%) had surgery on an inferior oblique alone (5 recession, 9 myectomy, 1 anteriorization), 9 (32%) on the superior oblique alone (7 tuck, 2 advance with or without resection), 1 (4%) on the superior rectus alone, and 3 (11%) on the inferior rectus alone (Table 1). Of the 45 undergoing two-muscle surgery, the majority (28, 62%) had a combination of inferior oblique weakening plus contralateral inferior rectus weakening (Table 1).

### Motor Success

At 6 weeks the motor success rate was similar for one-muscle surgery compared with two-muscle surgery (64% and 67% respectively, difference −2%, 95% CI −25% to 20%, P>0.99, Table 1). Of the 25 overall motor failures, 17 (68%) were undercorrected and 8 (32%) were overcorrected. Comparing surgical groups, proportionately more patients undergoing one-muscle surgery were undercorrected compared with those undergoing two-muscle surgery (36% vs 16%, difference 20%, 95% CI −1% to 41%, P=0.09), whereas the rate of overcorrection was significantly higher for those undergoing two-muscle compared with one-muscle surgery (18% vs 0%, difference 18%, 95% CI 7% to 29%, P=0.02).

For the 46 patients with 1 year outcome data, 29 undergoing two-muscle surgery and 17 undergoing one-muscle surgery, reoperation before the 1-year examination (resulting in assigned motor and diplopia failure) occurred for 8 (28%) patients undergoing two-muscle surgery and 3 (18%) undergoing one-muscle surgery. For these 46 patients, motor success at 6 weeks was 59% for one-muscle surgery compared with 62% for two-muscle surgery (difference −3%, 95% CI −33% to 26%, P>0.99), suggesting that cases with 1-year data were similar to the larger cohort who had 6-week data. For the entire cohort who had 1-year data, motor success at 1-year was 47% for one-muscle surgery compared with 55% for two-muscle surgery (difference −8%, 95% CI −38% to 22%, P=0.8, Table 2)

### Diplopia Success

In the sub-group of 58 patients with diplopia outcome data at 6 weeks, the motor success rate was the same to that for the entire data set (66% versus 66%, difference 0%, 95% CI −17% to 16%, P>0.99), indicating that these 58 are likely to be representative of the entire dataset. In these patients with diplopia data at 6 weeks, the diplopia success rate was somewhat similar for those undergoing one-muscle surgery (73%) compared with those undergoing two-muscle surgery (60%) (difference 13%, 95% CI −14% to 40%, P=0.5, Table 1).

Diplopia data were available for 20 of the 25 motor failures at 6 weeks (13 undercorrections and 7 overcorrections). There were significantly more diplopia successes in those who were undercorrected than in those who were overcorrected (62% vs 0%, difference 62%, 95% CI 35% to 88%, P=0.01). For the 46 patients with 1-year outcome data, 38 (83%) had data on diplopia status. Diplopia success at 6 weeks for the subgroup of patients with 1-year diplopia outcome data was 73% for one-muscle surgery compared with 44% for two-muscle surgery (difference 28%, 95% CI −4% to 61%, P=0.2), again suggesting that cases with 1-year data were similar to the larger cohort who had 6-week data. For patients with 1-year data, diplopia success at 1 year was 45% for one-muscle surgery compared with 59% for two-muscle surgery (difference −14%, 95% CI −49% to 21%, P=0.5, Table 2).

### Inferior oblique weakening alone versus in combination with contralateral inferior rectus weakening

Fifteen patients underwent inferior oblique weakening alone, and 28 underwent inferior oblique weakening in combination with contralateral inferior rectus recession. At 6 weeks, there was no difference in motor success rates between those undergoing a single inferior oblique recession (67% success) compared with those undergoing inferior rectus recession in addition to inferior oblique recession (64%, difference 2%, 95% CI 27% to 32%, P>0.99). The rate of undercorrection was not statistically different for those undergoing single inferior oblique recession (33% vs 14%, difference 19%, 95% CI −8% to 46%, P=0.2) and the rate of overcorrection was not statistically different for those undergoing inferior rectus recession in addition to inferior oblique recession (21% vs 0%, difference 21%, 95% CI 6% to 37%, P=0.08). Regarding diplopia, there was no statistically significant difference in the proportion of subjects had successful diplopia outcomes with a single inferior oblique recession compared with inferior rectus recession in addition to inferior oblique recession (100% vs 62%, difference 39%, 95% CI 20% to 57%, P=0.1).

Regarding the dose of inferior rectus muscle recession (in a post-hoc analysis), for the 28 patients who underwent inferior oblique weakening in combination with contralateral inferior rectus recession, the median recession of the contralateral inferior rectus (including adjustment, if performed on an adjustable suture) was 3 mm, range 1.5mm to 6 mm. Motor success at 6-weeks was similar between those who had an inferior rectus recession of 3mm or less versus those who had more than 3 mm (9/16 (56%) versus 9/12 (75%), difference −19% 95% CI −53% to 16%, p=0.4), and diplopia success was also similar at 6 weeks (9/15 (60%) versus 7/11 (64%), difference −4% 95% CI –−41% to 34%, p>0.99)

At 1 year, the motor success rate was not different between those undergoing a single inferior oblique recession (N=7; 57% success) compared with those undergoing inferior rectus recession in addition to inferior oblique recession (N=17; 47%, difference 10%, 95% CI −34% to 54%, P>0.99). The rate of undercorrection was not statistically different for those undergoing single inferior oblique recession (43% vs 18%, difference 25%, 95% CI −16% to 66%, P=0.3) and the rate of overcorrection was also not statistically different for those undergoing inferior rectus recession in addition to inferior oblique recession (35% vs 0%, difference 35%, 95% CI 13% to 58%, P=0.1). Regarding successful diplopia outcomes at 1 year, there were no statistically significant differences (60% vs 25%, difference 35% favoring two-muscle surgery, 95% CI −14% to 84%, P=0.3).

## Discussion

In the present study we found similar motor and diplopia success rates at 6 weeks and 1 year when performing one-versus two-muscle surgery for moderate hyperdeviations due to presumed unilateral fourth nerve palsy. There were more undercorrections with one-muscle surgery, and more overcorrections with two-muscle surgery, but undercorrections were associated with less diplopia.

Several previous studies have compared one-versus two-muscle procedures for hyperdeviation in the context of fourth nerve palsy but in previous studies, patients appear to have been selected for different surgical approaches based on certain preoperative characteristics. Morad et al[12] performed inferior oblique recession either alone, or in combination with vertical rectus recession, but the vertical rectus recession was added if the hyperdeviation increased 6 PD or more in the field of gaze ipsilateral to the paretic eye. Morris et al[13] reported that isolated superior oblique tuck was performed for hyperdeviations measuring 13 PD or less in primary position but that contralateral inferior rectus recession or ipsilateral inferior oblique recession was added if the deviation was 12 PD or more in primary and there was vertical incommitance. Hatz et al[1] evaluated the effectiveness of isolated inferior oblique weakening as a single-muscle procedure, but added contralateral inferior rectus weakening for larger angles of hyperdeviation. Wang and Flanders[8] reviewed patients undergoing either inferior oblique weakening, contralateral inferior rectus weakening or combined inferior oblique and inferior rectus weakening and reported that cases undergoing one-muscle surgery generally had less than 20 PD hyperdeviation in primary position whereas most of those undergoing two-muscle surgery had more than 20 PD.

In the present study, we compared one- and two-muscle surgical approaches in a group of patients with moderate hyperdeviation in primary position, who had not been systematically selected for either a one-muscle versus a two-muscle surgical approach. We found no statistically significant difference in motor success rates between one-muscle and two-muscle groups at 6 weeks or at 1 year. This finding of equally effective one-versus two-muscle surgery for motor alignment was confirmed in our planned subgroup analysis of patients undergoing either isolated inferior oblique weakening alone, or in combination with contralateral inferior rectus recession. These data suggest that when evaluating primary position motor alignment alone, there is no clear advantage of two-muscle surgery for the correction of moderate angle hyperdeviation in presumed unilateral fourth nerve palsy.

In the present study we defined motor success as a PACT measurement between zero and 4 PD of residual hyperdeviation, comparable to definitions used in previous studies. Morad et al[12] used a definition of 5 PD or less, Wang and Flanders[8] used less than 5 PD, Simons et al[3] used 3 PD or less, and Nejad et al[4] used 6 PD or less. Nevertheless, in some previous studies it is not clear whether the motor outcome definition included reversal of hyperdeviation. In other studies, motor outcomes are reported in terms amount of hyperdeviation corrected.[5–7] In the present study, we were interested in evaluating the effectiveness of surgery in reducing moderate angle hyperdeviation to a magnitude that the patient would be easily able to fuse, and for this reason we chose zero to 4 PD of residual hyperdeviation for defining motor success. Nevertheless, this threshold is somewhat arbitrary, and we recognize that an undercorrection of more than 4 PD is at times a satisfactory result to these patients, since the presence of extended vertical fusion ranges can enable comfortable control of a larger deviation. In contrast overcorrections appear to be particularly troublesome, often resulting in diplopia, and therefore we used a threshold of 1 PD or more reversal of hyperdeviation should be classified a motor outcome failure.

Many previous studies reporting outcomes following surgery for unilateral fourth nerve palsy report motor alignment only. However, evaluation of diplopia status is essential for providing a more complete picture of surgical outcomes.[11] Such outcome assessment is particularly important in the management of fourth nerve palsy since very small overcorrections (possibly meeting criteria for motor success) can be associated with debilitating diplopia. Morad et al[12] incorporated diplopia status in their definition of success, requiring elimination of diplopia in the central 30 degrees of binocular visual field. Morris et al[13] and Wang and Flanders[8] required elimination of diplopia in primary position at distance and for reading to be classified as success. Others describe elimination of diplopia but it is unclear how this was measured.[14, 15] In this particular condition, one could argue that the presence and severity of diplopia should be used as the primary outcome measure, because in contrast to most other types of strabismus, a residual large-angle deviation without diplopia is rare. In the present study we used the patient-reported Diplopia Questionnaire[10] data when available, or patient history if Diplopia Questionnaire data were unavailable, and we defined diplopia success as no diplopia (or only rare) for straight ahead distance and for reading. Using only diplopia criteria to define success we found no significant difference between one- and two-muscle procedures overall.

There are some limitations to the present study. The assignment of treatment was not randomized, which was reflected in slightly different preoperative angles for those undergoing one-versus two-muscle procedures, and it is likely that other factors may also have been imbalanced between groups. Due to the retrospective nature of the study and incomplete data on the surgeon's reason for each specific surgical plan, we cannot evaluate whether certain factors (e.g., superior oblique tendon laxity, torsion, forced ductions) influenced the choice of one procedure over another. We had a heterogeneous group of one- and two-muscle procedures (one muscle procedures included inferior oblique, superior oblique and vertical rectus), but our secondary analysis of patients undergoing inferior oblique weakening alone versus inferior oblique weakening plus contralateral inferior rectus weakening was not inconsistent with the primary analysis, although the confidence intervals were wide. In other studies, additional factors have been incorporated into the definition of success, including correction of compensatory head position, and subsequent need for reoperation. We did not evaluate these parameters in the present study since there were insufficient data regarding head posture, limited follow-up after 1 year, and reoperation rate could be influenced by the individual surgeon's preferences and coexisting neurologic conditions. In addition, we did not have standardized Diplopia Questionnaire[10] data on all patients and quantification of diplopia frequency may have been less accurate based on review of the history alone. Our motor outcome was based on primary position measurements and did not consider alignment in down or lateral gaze positions. Nevertheless we did use reading gaze when evaluating diplopia success. We did not perform multivariate regression analysis due to the number of patients and number of potential factors, and missing data. Our sample sizes for the 6-week and 1-year analyses resulted in fairly wide 95% confidence intervals, and so we may have missed a real effect, particularly one that fell within the calculated intervals. Finally, in addition to the issue of one versus two muscles we recognize that other factors, such as hyperdeviation incomitance,[16] degree of torsion, and degree of superior oblique tendon laxity,[17] may need to be considered when formulating the optimal surgical plan.

In patients with moderate hyperdeviation in the context of presumed unilateral fourth nerve palsy, there appears to be no clear advantage to performing two-muscle surgery over one muscle surgery (performed on inferior oblique, superior oblique or a vertical rectus muscle) when evaluating motor alignment alone at 6 weeks and 1 year. Overall, patients undergoing one-muscle surgery are more likely to be undercorrected and those undergoing two-muscle surgery are more likely to have symptomatic overcorrection, but diplopia success rates were similar between one- and two-muscle groups, due to a greater number of less symptomatic undercorrections with one-muscle surgery, and a small number of more symptomatic overcorrections with two-muscle surgery. Performing two-muscle surgery as an initial approach may have the disadvantage of a more difficult and possibly less predictable second surgery, but this has not been studied. Based on our present study, both one-muscle and two-muscle approaches appear reasonable for the management of presumed unilateral fourth nerve palsy associated with moderate hyperdeviation.

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## Table 1

Six-Week Outcomes for One-Muscle and Two-Muscle Surgery for Presumed Unilateral Superior Oblique Palsy.

| | | Motor Success (n=73) | | | Diplopia Success (n=58)[a] | | |
|---|---|---|---|---|---|---|---|
| | | Success | Under | Over | Success | Partial | Failure |
| **One muscle (n=28)** | **Overall** | **18 (64%)** | **10 (36%)** | **0 (0%)** | **11 (73%)** | **1 (7%)** | **3 (20%)** |
| | IO only (n=15) | 10 (67%) | 5 (33%) | 0 (0%) | 6 (100%) | 0 (0%) | 0 (0%) |
| | SO only (n=9) | 6 (67%) | 3 (33%) | 0 (0%) | 3 (60%) | 1 (20%) | 1 (20%) |
| | Rectus only (n=4) | 2 (50%) | 2 (50%) | 0 (0%) | 2 (50%) | 0 (0%) | 2 (50%) |
| **Two muscles (n=45)** | **Overall** | **30 (67%)** | **7 (16%)** | **8 (18%)** | **27 (61%)** | **7 (16%)** | **10 (23%)** |
| | IO+IR (n=28) | 18 (64%) | 4 (14%) | 6 (21%) | 16 (62%) | 4 (15%) | 6 (23%) |
| | IR+SR (n=8) | 6 (75%) | 0 (0%) | 2 (25%) | 3 (38%) | 2 (25%) | 3 (38%) |
| | SO+IR (n=7) | 5 (71%) | 2 (29%) | 0 (0%) | 5 (71%) | 1 (14%) | 1 (14%) |
| | SR+SO (n=1) | 1 (100%) | 0 (0%) | 0 (0%) | 1 (100%) | 0 (0%) | 0 (0%) |
| | Ipsilateral SO+SR (n=1) | 0 (0%) | 1 (100%) | 0 (0%) | 1 (100%) | 0 (0%) | 0 (0%) |

[a]For diplopia success and combined motor with diplopia success, 15 subjects with one-muscle surgery and 43 subjects with two-muscle surgery were available for analysis.

## Table 2

1-Year Outcomes for One-Muscle and Two-Muscle Surgery for Presumed Unilateral Superior Oblique Palsy.

| | | Motor Success (n=46) | | | Diplopia Success (n=38)[a] | | |
|---|---|---|---|---|---|---|---|
| | | **Success** | **Under** | **Over** | **Success** | **Partial** | **Failure** |
| **One muscle (n=17)** | **Overall** | **8 (47%)** | **9 (53%)** | **0 (0%)** | **5 (45%)** | **3 (27%)** | **3 (27%)** |
| | IO only (n=7) | 4 (57%) | 3 (43%) | 0 (0%) | 1 (25%) | 1 (25%) | 2 (50%) |
| | SO only (n=8) | 3 (38%) | 5 (63%) | 0 (0%) | 3 (60%) | 1 (20%) | 1 (20%) |
| | Rectus only (n=2) | 1 (50%) | 1 (50%) | 0 (0%) | 1 (50%) | 1 (50%) | 0 (0%) |
| **Two muscles (n=29)** | **Overall** | **16 (55%)** | **5 (17%)** | **8 (28%)** | **16 (59%)** | **4 (15%)** | **7 (26%)** |
| | IO+IR (n=17) | 8 (47%) | 3 (18%) | 6 (35%) | 9 (60%) | 1 (7%) | 5 (33%) |
| | IR+SR (n=6) | 3 (50%) | 1 (17%) | 2 (33%) | 3 (50%) | 2 (33%) | 1 (17%) |
| | SO+IR (n=5) | 4 (80%) | 1 (20%) | 0 (0%) | 3 (60%) | 1 (20%) | 1 (20%) |
| | SR+SO (n=1) | 1 (100%) | 0 (0%) | 0 (0%) | 1 (100%) | 0 (0%) | 0 (0%) |

[a]For diplopia success and combined motor with diplopia success, 11 subjects with one-muscle surgery and 27 subjects with two-muscle surgery were available for analysis.