ORIGINAL ARTICLE

Predictors of Good Motor and Sensory Outcomes Following Strabismus Surgery for Patients with Third Nerve Palsies*

Jason H. Peragallo^{1,2} Beau B. Bruce^{1,3,5}, Amy K. Hutchinson¹, Phoebe D. Lenhart¹,
Valérie Biousse^{1,3}, Nancy J. Newman^{1,3,4}, and Scott R. Lambert¹

¹Departments of Ophthalmology, ²Departments of Pediatrics, ³Departments of Neurology, and ⁴Departments of Neurological Surgery, Emory University School of Medicine, Atlanta, Georgia, USA, and ⁵Department of Epidemiology, Rollins School of Public Health and Laney Graduate School, Emory University, Atlanta, Georgia, USA

ABSTRACT

Strabismus from third nerve palsy (3NP) is difficult to treat. Our goal was to explore factors associated with successful surgical outcomes in 3NP. Institutional records of all adult patients (>18 years) from 1988 to 2012 with 3NP who underwent strabismus surgery or botulinum toxin injections were retrospectively reviewed. Success was defined as absence of diplopia, vertical deviation ≤ 2 prism dioptres (PD), and horizontal deviation ≤ 10 PD. Fifty-six patients from four surgeons were included. Thirty (54%) were female; mean age was 48 (range: 20–80). Forty-four (79%) had unilateral 3NP; 9 (16%) had other ocular motor nerve palsies. 3NP were complete in 24 (43%). Underlying aetiology was idiopathic/microvascular in 5 (9%), traumatic in 13 (23%), neoplastic in 12 (21%), aneurysmal in 10 (18%), and other central nervous system related in 16 (29%). Trauma was associated more frequently with aberrant regeneration than other aetiologies: 9/13 (69%) versus 4/43 (9%) ($p < 0.01$). Ten patients (18%) had >1 surgery. Surgical success was achieved in 28/56 (50%). Success rate was unaffected by aetiology, degree of palsy, pupillary involvement, presence of aberrant regeneration, or number of other cranial nerves involved. However, adjustable sutures were used in 27 patients (48%), and there was a trend toward higher success rates when adjustable versus nonadjustable sutures were used (63% versus 38%; $p = 0.06$). Unlike with sixth nerve palsies, the aetiology and degree of 3NP does not appear to affect the success rates or number of procedures performed. Strabismus surgeries for 3NP with adjustable sutures may be associated with better outcomes.

Keywords: Adjustable suture, cranial nerve palsy, diplopia, strabismus, third nerve palsy

INTRODUCTION

Strabismus in adults can lead to disabling diplopia and torticollis and can affect social interactions due to decreased self-esteem.^{1,2} Ocular motor nerve palsies are an important cause of adult onset strabismus. Previous reports have stated the frequency of isolated oculomotor nerve palsy, among all ocular motor nerve palsies leading to strabismus, at about 20–30%, and

multiple cranial nerve palsies including oculomotor nerve palsies leading to strabismus at about 10%.^{3,4} Extraocular muscle surgery may be performed to improve ocular alignment and alleviate symptoms.

Oculomotor nerve palsies can be extremely difficult to treat with surgery due to the complex incomitant strabismus patterns that they cause. Aberrant regeneration may add an additional level of complexity to strabismus surgery for these patients. To this end,

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Correspondence: Dr. Jason Peragallo, Department of Ophthalmology, Emory University School of Medicine, 1365-B Clifton Road NE, Atlanta, GA 30322, USA. E-mail: jperaga@emory.edu

multiple methods for correcting complete ocular motor nerve palsy have been described in patients both with and without aberrant regeneration, including large recess-resect procedures,⁵ superior oblique tendon transfer,^{6,7} lateral rectus muscle periosteal fixation,⁸ suture fixation of the globe to the perosteum,^{9,10} and myectomy of the lateral rectus muscle.¹¹ Motor criteria alone are frequently reported in outcomes from extraocular muscle surgery, but this may lead to inflated rates of success, given that patients may continue to experience disabling diplopia and decreased quality of life.^{12–14}

Our primary goal was to evaluate the motor and sensory outcomes of extraocular muscle surgery for oculomotor nerve palsies. Secondary goals were to further examine outcomes based on aetiology, degree of palsy, presence of aberrant regeneration, and use of adjustable sutures.

SUBJECTS AND METHODS

This study was approved by the Emory University Institutional Review Board and conformed to the requirements of the Declaration of Helsinki and the United States Health Insurance Portability and Accountability Act. The clinical records of all patients at Emory University over the age of 18 years who underwent strabismus procedures from 1988 to 2012 were identified by use of strabismus and neurologic ICD-9 (International Classification of Diseases, ninth revision) codes (191.X, 192.0, 192.1, 237.7x, 237.9, 324.0, 325, 340, 341.0, 341.20–341.22, 341.8, 341.9, 378.5x, 378.72, 378.73, 378.8x), manual review of operative reports in combination with strabismus Current Procedural Terminology (CPT) codes (67311–67320, 67332–67335), and by surgical case logs prior to the institution of electronic medical records or electronic billing data. From these operative reports, retrospective chart review of patients with acquired oculomotor nerve palsies who underwent strabismus procedures (incisional extraocular muscle surgery or botulinum toxin injection) was performed.

Data identified and recorded from patient medical records included age at first strabismus procedure, gender, medical history, aetiology of oculomotor nerve palsy, best-corrected visual acuities in each eye, ability to fuse (for patients who were not effectively monocular due to poor vision in one eye), presence or absence of diplopia pre- and postoperatively, preoperative horizontal and vertical motor alignment in all cardinal positions at distance, and rotation limitations as per the scale described by Scott and Kraft (duction of 0 = normal, –1 = rotate from midline to 75% of full rotation, –2 = rotate from midline to 50% of full rotation, –3 = rotate from midline to 25% of full rotation, –4 = rotate to midline but not into given field, and –5 = unable to rotate from opposite field to midline).¹⁵

Patients were classified as complete or partial oculomotor palsies on the basis of their ductions and presence of ptosis on initial presentation (for patients with bilateral oculomotor palsies, the more severely affected eye was used for analysis). Additional data reviewed included the presence and degree of torsion (in patients who complained of torsion, $n = 5$), involvement of the pupil, the presence and type of aberrant regeneration, the presence of head turn pre- and postoperatively, surgical procedure performed, use of adjustable sutures, immediate postoperative deviation prior to adjustment, postoperative deviation after adjustment, and amount of adjustment performed (if performed). If a second procedure was performed on an individual patient, the type of procedure, use of adjustable sutures, and adjustment were all recorded and analysed. All incisional surgical procedures were performed at least 6 months after onset of oculomotor palsy. Best-corrected visual acuity was measured in each eye using Snellen optotypes after manifest refraction. Ocular alignment with spectacle correction was assessed using cover/uncover testing and prism and alternate cover testing at distance (6 m) in cardinal gaze positions when possible, otherwise by Krimsky light reflex testing. Ocular motor alignment in primary position, presence or absence of diplopia, and presence of head turn were assessed at subsequent pre- and postoperative visits if further strabismus procedures were performed, and at every subsequent follow-up visit until discharge or loss to follow-up. Patients with incomplete preoperative or postoperative data were excluded from analysis. Any patient without a follow-up visit at least 28 days following their initial strabismus procedure was excluded from analysis.

The aetiology of oculomotor palsy was categorised into five groups: (1) traumatic, (2) neoplastic, (3) aneurysmal, (4) idiopathic/microvascular, and (5) other central nervous system lesions.

For the purposes of analysis and comparison, the preoperative deviation was given a positive (“+”) value and overcorrections were negative (“–”). Treatment success was defined by both motor and sensory criteria. Motor criteria for success included a horizontal deviation ≤ 10 prism dioptres (PD) and a vertical deviation ≤ 2 PD in primary position looking in the distance. Sensory criteria for success were the absence of diplopia in primary position allowing for use of prisms or near primary position allowing for a small face turn. Patients were deemed to have a successful outcome if both motor and sensory criteria were satisfied. Monocular patients were assessed using motor criteria alone.

Statistical analysis was performed using the R: A language and environment for statistical computing (R Foundation for Statistical Computing, <http://www.R-project.org>). Medians were reported for continuous data; percentages were reported for categorical data. Medians were compared using the Mann-Whitney

U test, and proportions were compared using χ^2 or Fisher exact tests, as appropriate. Logistic regression was used to determine the association of age with success and multiple procedures. Two-tailed *p* values <0.05 were considered statistically significant.

RESULTS

We reviewed 1889 operative reports and identified 56 (3%) patients with acquired third nerve palsies who underwent strabismus procedures and met our inclusion criteria. Mean patient age was 48 (range: 20–80), 30 (54%) were female, 24 (43%) had complete oculomotor nerve palsies versus partial oculomotor nerve palsies, 10 (18%) underwent previous strabismus procedures, and 12 (21%) had bilateral oculomotor nerve palsies. Nine patients (16%) had other ocular motor nerve palsies in addition to third nerve palsies. One patient underwent a botulinum toxin A injection alone, without incisional strabismus surgery. Median follow-up time was 80 days (interquartile range [IQR]: 32–246 days).

The aetiologies of oculomotor nerve palsy were 13 (23%) traumatic, 12 (21%) neoplastic, 10 (18%) aneurysmal, 5 (9%) idiopathic/microvascular, and 16 (29%) other central nervous system causes. Other central nervous system abnormalities included parenchymal infarction or haemorrhage, meningitis, arterial-venous malformation with haemorrhage, cavernous-carotid fistula, and multiple sclerosis. Oculomotor palsies were complete in 24 (43%). The frequency of complete oculomotor palsy was similar across aetiologies: 62% (8/13) for traumatic, 42% (5/12) for neoplastic, 30% (3/10) for aneurysm, 20% (1/5) for microvascular/unknown, and 44% (7/16) for other central nervous system (*p*=0.5). Initial surgeries performed for these patients are given in Table 1.

The median preoperative horizontal deviation was 35 PD (IQR: 18–53.75). The median postoperative horizontal deviation was 6 PD (IQR: 0–16). The median preoperative vertical deviation was 12 PD (IQR: 8–18). The median postoperative vertical deviation was 4 PD (IQR: 0–10).

A successful outcome using a combination of motor and sensory criteria was achieved in 28 (50%) patients. Success rates using a stricter definition of success, excluding use of a face turn or prisms to achieve binocular single vision in primary position decreased overall success rates to 36%, but did not otherwise affect our outcomes. Success rate was achieved using motor criteria alone in 31 (55%) patients. Age and length of follow-up did not influence the rate of success or frequency of repeat surgery. The final rates of surgical success based on aetiology were 53% (6/13) for traumatic, 33% (4/12) for neoplastic, 40% (4/10) for aneurysmal, 60% (3/5) for microvascular/unknown, and 63% (10/16) for other

central nervous system causes (*p*=0.58). Patients with partial oculomotor palsies had similar success rates (17/32, 53%) to those with complete oculomotor nerve palsies (11/24, 46%; *p*=0.59), with success defined by our motor and sensory criteria in primary position at distance.

The pupil was involved on presentation to the strabismus service in patients with oculomotor nerve palsies from trauma 85% (11/13), neoplasms 75% (8/12), aneurysms 70% (7/10), microvascular/unknown 20% (1/5), and other central nervous system causes 31% (5/13). The pupil was more likely to be involved in oculomotor nerve palsies from aneurysms, neoplasms, and trauma (77%) versus other central nervous system causes and microvascular/unknown (29%; *p*<0.01). The presence of pupil involvement did not significantly affect success rates (42% versus 61%; *p*=0.17).

Aberrant regeneration only occurred in oculomotor palsies from trauma 69% (9/13), aneurysms 30% (3/10), and neoplasms 8% (1/12), in comparison with other central nervous system causes 0% (0/16) and microvascular/unknown 0% (0/5) (37% versus 0%; *p*=0.001). Traumatic oculomotor palsies were associated with an increased risk of aberrant regeneration in comparison with all other aetiologies (traumatic, 69% [9/13]; other, 9% [4/43]; *p*<0.01). Success rates were similar for patients with and without aberrant regeneration (51% versus 46%; *p*=0.75).

Patients who had surgery with an adjustable suture had a higher rate of overall success (adjustable, 17/27 [63%]; no adjustable 11/29 [38%]; *p*=0.06). There were 10 patients who underwent more than one surgery at our institution. Seven patients had

TABLE 1 Initial procedures performed for patients with third nerve palsies.

Procedure	Number of patients
Horizontal rectus muscle recession and resection procedures	25
Horizontal rectus muscle recession and resection procedures with vertical rectus muscle recession and/or resection procedures	11
Botulinum A toxin injection	1
Lateral rectus disinsertion with or without periosteal fixation	6
Vertical rectus muscle recession and resection procedures	5
Knapp or inverse Knapp procedure	2
Vertical rectus transposition	2
Hummelsheim procedure with or without horizontal rectus muscle recession and/or resection procedures	2
Harada-Ito procedures with vertical rectus muscle procedures	1
Inferior oblique recession	1

two surgeries, three patients had three surgeries. The patients who underwent more than one surgery had the same success rate as those who underwent a single surgery (multiple surgeries, 5/10 [50%]; single surgery, 23/46 [50%]; $p=1.00$). All three patients who underwent three surgeries were considered treatment failures by our criteria for success in this study. The frequency of requiring more than one surgery by cause were 15% (2/13) for traumatic, 17% (2/12) for neoplastic, 10% (1/10) for aneurysmal, 20% (1/5) for microvascular/unknown, and 25% (4/16) for other central nervous system disease ($p=0.93$).

DISCUSSION

Although the rate of spontaneous recovery of oculomotor palsies has been reported as high as 84%, with complete recovery in 64–68%, surgical treatment is an important part of the management of many of these patients.^{3,4,16} Several single-case reports and small series have described various methods of surgical correction for oculomotor nerve palsies. Overall surgical success rates for larger cohorts undergoing extraocular muscle surgery for oculomotor nerve palsy have not been discussed in detail. In our study, we found that patients had similar rates of success independent of the underlying aetiology of their oculomotor nerve palsy. Additionally, the degree of oculomotor nerve palsy, presence of aberrant regeneration, and presence of multiple cranial nerve palsies did not influence success rates or the rate of requiring more than one procedure to achieve a successful outcome.

The choice to allow the use of prism or a head position in our definition of success was secondary to the complexity of strabismus surgery for third nerve palsy patients, which often included both horizontal and vertical deviations, with multiple extraocular muscles involved in the oculomotor nerve paresis. Changing the definition of success to exclude the possibility of use of prisms or head turn decreased the overall success rate to 36%, but did not influence any of the other conclusions (data not shown).

Interestingly, our data show that partial oculomotor palsies do not appear to have a higher likelihood of successful outcomes than complete palsies (partial, 53%; complete, 46%). This runs contrary to commonly held belief that complete oculomotor nerve palsies are one of the more challenging deficits to correct for strabismus surgeons. This could be due to the relatively short follow-up, our small sample size, or our definition of success (e.g. alignment in primary position at distance).

Adjustable suture techniques have been proposed to improve surgical outcomes in strabismus surgery. Debate on the subject of adjustable sutures continues, and their use remains controversial.¹⁷ Many studies

have found adjustable sutures to be a beneficial technique.^{18–20} In our study, patients who underwent strabismus surgery with adjustable sutures were more likely to have a successful outcome (adjustable, 63%; no adjustable, 38%), but this difference did not quite reach significance ($p=0.06$), likely due to the small sample size.

Our study has multiple limitations. First, we may have had a skewed population, since we are a tertiary referral centre. Second, data were obtained retrospectively from historical chart review and were not always consistently documented. Third, we do not routinely perform binocular single vision fields pre- and post-operatively. These visual fields would provide more objective data on the improvement in quality-of-life for our patients through the elimination of diplopia. Finally, force generation testing or eye movement recordings would have improved our understanding of whether contracture of a rectus muscle, or true rectus muscle palsy, caused a “complete” motility deficit.

Our series has several strengths. First, it is one of the largest series of adults with oculomotor palsies who have undergone strabismus surgery. Second, multiple surgeons performed the surgeries.

We combined multiple types of strabismus procedures in our outcome analysis. A prospective randomised trial comparing strabismus procedures for partial and complete oculomotor nerve palsy would be ideal but is almost certainly impossible to perform. Instead, we suggest that a prospective, multicentre observational registry with well-defined pre- and postoperative assessments would provide quality data about the presentation and outcome of oculomotor nerve palsies and their treatment, as in Holmes’ work for abducens nerve palsy.^{21–24}

Patients who underwent strabismus surgery for oculomotor nerve palsies had similar outcomes using motor and sensory criteria despite variances in degree and aetiology of their oculomotor nerve palsy, or presence of aberrant regeneration. Patients who undergo strabismus procedures with adjustable sutures may have a higher rate of success, but further study in well-characterised, multicentre populations would be beneficial to validate these preliminary findings.

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