

ORIGINAL ARTICLE

Functional and Motor Outcomes of Strabismus Surgery for Chronic Isolated Adult Sixth Nerve Palsy*

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ABSTRACT

Abducens nerve palsy is the most common acquired ocular motor nerve palsy in adults. Chronic cases of abducens palsy often require surgical intervention to relieve disabling diplopia. The goal of this study was to identify factors associated with surgical outcomes in isolated abducens palsy. Medical records of all adult patients from 1988 to 2012 with abducens palsies who underwent strabismus procedures were retrospectively reviewed. Motor alignment, extraocular motility, and sensory outcomes were recorded. Success was defined as absence of diplopia without prisms or face turn, vertical deviation ≤ 2 prism dioptres (PD), and horizontal deviation ≤ 10 PD. Eighty-one patients (age range: 20–86 years) met inclusion criteria. Success was achieved in 58% of patients. Final success rates for abducens palsy were 50% for neoplastic, 59% traumatic, 57% for microvascular/unknown, and 67% for other central nervous system causes ($p > 0.05$). Patients with an underlying neoplastic or traumatic aetiology required more than one strabismus procedure more often than those with microvascular/idiopathic or other central nervous system causes (48% vs. 24%; $p = 0.03$). For complete abducens palsies, patients who underwent Hummelsheim-type procedures had a higher success rate than those who underwent a full-tendon vertical rectus muscle transposition. (78% versus 35%; $p = 0.049$). Success rates for strabismus procedures in patients with abducens palsies are similar across all aetiologies. Frequency of re-operation is higher among those patients with neoplastic or traumatic aetiologies for their abducens palsies. Hummelsheim-type procedures have a higher success rate for complete abducens palsies than full-tendon vertical rectus transpositions.

Keywords: Adjustable suture, cranial nerve palsy, hummelsheim, paralytic strabismus, sixth nerve palsy

INTRODUCTION

Strabismus is estimated to occur in adults at a rate of approximately 4% and can cause disabling diplopia and torticollis with a resultant decrease in the patient's quality of life.¹ Sixth nerve palsy is the most frequent cause of acquired paralytic strabismus among adults.^{2,3} Improvement in extraocular alignment alone, used as the sole criteria for success in many strabismus studies, may not relieve disabling

symptoms, or improve quality of life for the patient.^{4–7} Studies of the efficacy of strabismus surgery in adults most frequently examine motor criteria alone, giving artificially elevated success rates for patients who may be unhappy with their surgical outcome due to continued diplopia or poor quality of life.⁸

Our primary aim was to examine both motor and sensory outcomes of extraocular muscle surgery for sixth nerve palsy. Secondary goals were to further examine outcomes based on aetiology, degree of palsy,

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use of adjustable sutures for partial abducens palsy, and type of procedure performed for complete sixth nerve palsy.

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 by one of four strabismus surgeons 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 case logs prior to the institution of electronic medical records or electronic billing data. From these operative reports, retrospective chart review of patients with isolated acquired abducens 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, sex, medical history, aetiology of sixth 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 primary position at distance, and abduction limitation as per the scale described by Scott and Kraft⁹ (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).⁹ Abduction deficits of -4 or -5 were classified as complete, whereas abduction deficits of -1, -2, or -3 were classified as incomplete^{10–13} (for patients with bilateral abducens palsies, the more severely affected eye was used for analysis, as per previous studies).^{12,13} Additional data reviewed included the presence and degree 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 at Emory, the type of procedure, use of adjustable sutures, and adjustment

were all recorded and analysed. To account for planned staged strabismus procedures (i.e. a vertical rectus muscle transposition [VRT] followed by ipsilateral medial rectus muscle botulinum A toxin injection), two procedures performed within 28 days were considered as a single procedure. Any procedure performed beyond 28 days following the first procedure was considered a second procedure, even if it was planned (e.g. medial rectus muscle recession 6 months following full-tendon VRT). All incisional surgical procedures were performed at least 6 months after onset of abducens palsy. Patients with vasculopathic abducens palsy underwent surgery if there was no spontaneous resolution. 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 and degree 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 abducens paresis or palsy was categorised into four groups: (1) neoplastic, (2) traumatic, (3) idiopathic/microvascular, and (4) other central nervous system lesions.

For the purposes of analysis and comparison, the preoperative deviation was given a positive (“+”) value and overcorrections were deemed negative (“-”) deviations, as described in Peragallo et al.¹⁴ Treatment success was defined by both motor and sensory criteria. Motor success included a horizontal deviation <10 prism dioptres (PD), and a vertical deviation <2 PD in primary position without a face turn. Sensory criteria for success were the absence of diplopia in primary position without the use of prisms or a face turn. 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 81 patients (4%) with isolated chronic acquired sixth nerve palsies who underwent strabismus procedures at Emory University and met our inclusion criteria. Demographic data for these patients are presented in Table 1. Ten patients underwent botulinum toxin A injections alone, without incisional strabismus surgery. One surgeon performed 57 of the procedures, a second surgeon performed 20 of the procedures, and two surgeons performed two procedures each.

The aetiologies of sixth nerve palsy were 18 (22%) neoplastic, 22 (27%) traumatic, 23 (28%) idiopathic/microvascular, and 18 (22%) other central nervous system causes. Other central nervous system abnormalities included parenchymal infarction or haemorrhage, arterial-venous malformation with haemorrhage, cavernous-carotid fistula, multiple sclerosis, and giant cell arteritis. Neoplastic and traumatic groups were more likely to have complete sixth nerve palsies in comparison to other aetiologies (58% versus 24%; $p = 0.002$).

Overall successful outcome using a combination of motor and sensory criteria was achieved in 58% of patients. Age did not influence the rate of success or repeat surgery (odds ratio [OR] = 0.98–1.0, 95% confidence interval [CI]: 0.94–1.06; $p > 0.10$). There was no difference in the rates of surgical success based on aetiology: final success rates for abducens palsy by cause were 50% for neoplastic, 59% for traumatic, 57% for microvascular/unknown, and 67% for other central nervous system causes. Patients with partial abducens palsies were more likely to have a successful outcome (32/48, 67%) compared with patients with complete abducens palsies (15/33, 45%; $p = 0.057$). Patients who had an adjustable suture used during surgery had a higher rate of overall success at 71% (20/28), compared with 49% (21/43) without adjustable sutures ($p = 0.06$). The rates

TABLE 1 Demographics of 82 patients with isolated chronic acquired sixth nerve palsies who underwent strabismus procedures.

Characteristic	Number	Percent
Female	49	60%
Age, years (range)	51 (20–86)	
Complete ^{a,b}	33	40%
Previous procedures	12	15%
Bilateral ^c	17	21%
Treatment with botulinum toxin A alone	10	12%
Length of follow-up, days (interquartile range)	641 (81–356)	

^aComplete sixth nerve palsy defined as -4 or -5 abduction deficit as per Scott and Kraft.⁹

^bVersus partial sixth nerve palsy.

^cVersus unilateral.

of success for adjustable versus non-adjustable sutures were unaffected by degree of palsy (evaluated because some patients with complete abducens palsies had their medial rectus muscle placed on an adjustable suture when a Hummelsheim procedure was performed). Of the 34 patients who were treatment failures, 20 were due to motor criteria prior to the application of sensory criteria: 16 patients had undercorrections, and four patients had overcorrections. There were no induced vertical deviations. The rates of requiring more than one surgery by cause were 50% for neoplastic, 45% for traumatic, 35% for microvascular/unknown, and 11% for other central nervous system disease. Patients with an abducens palsy from a neoplastic or traumatic aetiology were more likely to require more than one strabismus procedure (including procedures performed prior to presentation to our institution) (48% versus 24%; $p = 0.03$). Among patients with only partial abducens palsies, those with a traumatic or neoplastic aetiology were more likely to require more than one surgery than those with other aetiologies (35% versus 13%; $p = 0.067$).

For complete abducens palsies, a Hummelsheim-type procedure was performed in nine patients, whereas a VRT was performed in 23 patients. Prior to the publication of Couser *et al.*,¹⁵ medial rectus muscle recession was not combined with the Hummelsheim procedure at our institution; therefore, a smaller number of individuals underwent Hummelsheim-type procedures than VRT during the study timeframe. There was no difference in initial esotropia or initial abduction deficit between patients who underwent a Hummelsheim-type procedure or a VRT (Table 2). Within the VRT group, nine patients underwent the surgical procedure with a combined botulinum toxin injection to the medial rectus muscle. Two of the nine patients (22%) who received botulinum toxin injections in addition to VRT achieved a successful outcome, whereas six of the 14 patients (43%) who did not receive botulinum toxin injections achieved a successful outcome ($p = 0.31$). For the patients who underwent a Hummelsheim-type procedure, five patients underwent augmented Hummelsheim procedures with combined medial rectus muscle recession as previously described,¹⁵ whereas four patients underwent Hummelsheim procedures with posterior fixation sutures as

TABLE 2 Characteristics for patients undergoing VRT or Hummelsheim procedures.

Metric	Hummelsheim ($n = 9$)	VRT ($n = 23$)	p Value
Initial esotropia	41.7 PD	48.1 PD	0.75
Initial abduction deficit	-4.0	-4.1	0.75
Success	7 (78%)	8 (35%)	0.049

previously described¹⁶ without simultaneous combined medial rectus muscle recession. Patients who underwent a Hummelsheim procedure had a higher rate of success compared with patients who underwent a VRT ($p=0.049$; Table 2).

DISCUSSION

The epidemiology and natural history of the various aetiologies of acquired sixth nerve palsies have been described in detail previously.² Spontaneous recovery of function in patients who have vasculopathic or traumatic aetiologies for their abducens palsy occurs frequently (in up to 73% of cases)^{10,17}; however, traumatic sixth nerve palsies are less likely to recover when there is inability to abduct beyond midline and when the palsy is bilateral.¹¹ What has not been fully examined is how the outcomes of strabismus procedures differ across the aetiologies of sixth nerve palsy. We found that patients had similar rates of overall success independent of aetiology, but that patients with traumatic or neoplastic causes had a higher rate of complete sixth nerve palsy and required more surgical procedures to achieve a successful outcome. Even patients with partial abducens palsies and a traumatic or neoplastic aetiology were more likely to require multiple procedures, suggesting there is a difference due to an underlying characteristic of the aetiology. This should be communicated to patients when consenting them for strabismus procedures.

Our study considered stringent criteria for successful strabismus surgery. One previous study of strabismus surgery for chronic sixth nerve palsy from all aetiologies reported an overall success rate of strabismus surgery of 52% when applying stringent criteria (<10 PD of tropia and absence of diplopia) to define success.¹³ This success rate is similar to what we found in our study (58%). However, when this same study allowed for the possibility of use of prism or a small face turn to correct diplopia, the success rate reached 75%.¹³ Also in the same study, although partial sixth nerve palsies had a higher rate of complete success (59%) compared with complete sixth nerve palsies (33%), the differences were not found to be significant.¹³ Even with our larger sample size, we found similar findings: patients with partial sixth nerve palsies had a higher, but not statistically significant, frequency of complete success in comparison with complete sixth nerve palsies.

A proposed method to improve the frequency of a successful strabismus surgery outcome is the adjustable suture. The adjustable suture technique has been described as a method to correct residual deviations in the immediate postoperative period. The use of adjustable sutures remains controversial, and no randomised controlled prospective studies have been performed.¹⁸ However, many other studies

have found a benefit to the adjustable suture technique.^{19–21} Outcomes of the use of adjustable sutures specifically for abducens paresis has not been previously evaluated to our knowledge. We found that patients who underwent adjustable sutures were more likely to have a successful outcome (71% versus 49%), but this difference was not statistically significant, likely due to our small sample size.

For complete sixth nerve palsies, our comparison of two commonly performed procedures found a significantly higher rate of success among patients who underwent Hummelsheim-type procedures (78% versus 35%). Many of the patients who had a Hummelsheim-type procedure underwent simultaneous medial rectus muscle recession. This may have improved the outcomes for these patients by relieving restrictions on motility imposed by a tight medial rectus muscle. Another method of potentially relieving medial rectus muscle restriction in sixth nerve palsy is a botulinum toxin injection to the medial rectus muscle.²² However, we did not find a benefit to using botulinum toxin injections in achieving complete success for patients who underwent VRT procedures, although sample size was small. No patient who underwent a Hummelsheim procedure received a botulinum toxin injection in our study. A direct comparison of outcomes of Hummelsheim procedures with and without augmentation would help in determining why these patients have a higher rate of success. Further evaluation of the use of botulinum toxin in patients undergoing Hummelsheim procedures would be beneficial.

This retrospective study has several limitations. Data on presence or absence of diplopia were obtained from historical data, which are always difficult to assess in retrospective chart reviews. We do not routinely perform binocular single vision fields in our patients, but these results would be valuable. Saccadic velocities and the results of forced duction testing were not consistently recorded, which would add valuable information regarding residual palsy versus medial rectus muscle contracture. Our results are also limited by short follow-up times for many patients, as several were discharged from our service 1 month postoperatively. Additionally, in this study, abducens palsies with a –4 or –5 abduction deficit were classified as “complete,” as they have been in several previous studies,^{10–13} but it is possible that these patients had contracture of the medial rectus muscle that limited abduction, biasing the classification of abducens palsies as partial or complete. Force generation testing or eye movement recordings would have improved our understanding of whether contracture of the ipsilateral medial rectus, or true lateral rectus muscle palsy, caused a “complete” abduction deficit. Although many ophthalmologists traditionally wait 6 months for spontaneous abducens nerve function recovery to occur, successful outcomes with

conservative management can occur beyond the 6-month time period.¹² Nevertheless, if spontaneous improvement occurs more frequently among microvascular palsies than traumatic/neoplastic palsies even 6 months after onset, then we would expect that a longer preoperative waiting period would only strengthen the conclusion that a higher number of repeat procedures is required for traumatic/neoplastic palsies compared to other causes.

For complete sixth nerve palsies, we only compared two of the most commonly performed transposition procedures at our institution. Other procedures such as the Jensen procedure, vertical rectus muscle splitting with transposition without tenotomy,²³ and vertical rectus muscle transposition without tenotomy as described by Nishida *et al.*^{24,25} were not evaluated. Recently, we have adopted the augmented superior rectus muscle transposition with medial rectus muscle recession as described by Mehendale *et al.*; however, this study period did not include those patients.²⁶ Future studies may include a direct comparison of this technique versus the Hummelsheim and VRT procedures. Finally, each of the three surgeons represented in this study may have subtle variations in procedure or postoperative examination techniques (e.g. not recording small face turns, especially if the patient had no complaints). However, these variations would have had to have been differentially applied across the aetiologies of sixth nerve palsy to affect our conclusions. One advantage of this series is the inclusion of patients who have undergone surgeries prior to presentation to our institution, as this reflects the reality many strabismus surgeons face. Another advantage is the strict definition of a successful outcome, even though some patients may have been satisfied with their outcome despite failing to meet our strict criteria.

Patients with neoplastic or traumatic causes for isolated chronic abducens palsy have the same success rate for surgical procedures to correct strabismus, but they should be counselled that they have a higher likelihood of requiring multiple procedures to achieve that success. Adjustable sutures may improve success rates and Hummelsheim-type procedures may have a higher rate of success compared with VRT for complete abducens palsies, but both of our conclusions deserve validation in randomised clinical trials.

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