Strabismus After Ahmed Glaucoma Valve Implantation

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• PURPOSE: Most reports of strabismus after glaucoma drainage device implantation study larger devices and rarely note the incidence of strabismus after Ahmed glaucoma valve (AGV) implantation. It is unknown if the pattern of strabismus is similar with smaller devices. We investigated characteristics of strabismus after AGV implantation.

• DESIGN: Retrospective review.

• METHODS: Institutional study of 732 patients at our institution undergoing AGV implantation between 2013 and 2018. Rate and characteristics of strabismus were the primary outcome; age, gender, and location of AGVs were also analyzed.

• RESULTS: We identified 29 patients who developed new-onset strabismus postoperatively after initial AGV implantation, for 4% incidence of strabismus. Twenty-one (72%) of these had diplopia. AGVs were implanted superotemporally in 21, superonasally in 5, inferotemporally in 1, and inferonasally in 2. Three patients were esotropic, 11 were exotropic, 4 had hypertropia, 2 had hypotropia, and 9 patients had combined horizontal/vertical strabismus (esotropia/hypotropia [n = 1] or exotropia/hypertropias [n = 8]). Exotropia was the most common type of strabismus in both the superotemporal and superonasal (60%) AGV groups. Superotemporal AGVs were more commonly associated with ipsilateral hypertropia (43%) than superonasal AGVs. Treatments included strabismus surgery (n = 14), prisms (n = 6), or an occlusive lens (n = 1).

• DISCUSSION.: In the largest single-center series of patients undergoing initial AGV implantation, the overall incidence of postoperative strabismus was 4%. This is comparable to strabismus incidence following implantation of other types of glaucoma drainage devices, even larger devices. The possibility of this complication should be discussed with patients prior to surgery. (Am J Ophthalmol 2021;222:1–5. © 2020 Elsevier Inc. All rights reserved.)

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INTRODUCTION

GLAUCOMA DRAINAGE DEVICES PLAY AN IMPORTANT role in the management of medically refractory or secondary glaucoma. Although these devices are crucial in glaucoma treatment, they are associated with several potential complications. Motility disturbance, strabismus, and diplopia have been described after implantation of glaucoma drainage devices. Several studies have evaluated the incidence of diplopia after implantation of various models. In the largest study reporting motility results, the Tube vs Trabeculectomy Study, there was motility disturbance in 5% of the 101 subjects who underwent implantation of a Baerveldt 350 (Abbott Medical Optics, Santa Ana, California, USA) glaucoma implant.[1,2] Although the more recent Ahmed Baerveldt Comparison Study reported an incidence of diplopia close to 12% for both the Ahmed FP7 (12.7%, New World Medical Inc, Rancho Cucamonga, California, USA) and Baerveldt 101-350 devices (11.8%),[3] this study was designed to evaluate the efficacy of device and only included motility examinations as performed by glaucoma specialists during study visits and did not include detailed motility examinations by strabismus specialists in cases of induced strabismus or diplopia. Similarly, the Ahmed vs Baerveldt Study aimed mainly to compare the efficacy of the 2 devices but reported a motility disorder in 5% and 2% of the Ahmed glaucoma valve (AGV) and Baerveldt patients, respectively.[4]

There are no large studies focused primarily on assessing strabismus after the implantation of an AGV as has been reported for the Baerveldt as part of the Tube vs Trabeculectomy study. Given the large number of AGV procedures performed annually at our institution, we aimed to review the charts of all patients undergoing implantation of an AGV and determine the incidence and characteristics of subsequent postoperative strabismus.

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TABLE 1. Characteristics of Patients Undergoing Ahmed Glaucoma Valve Surgery

	Strabismus (n=29)	Nonstrabismus (n=703)	*P* Value
Age, y, mean ± SD (range)	46.2 ± 29 (0 to 85)	64.9 ± 21 (1 to 97)	<.0001[a]
Location of first AGV (strabismus) or final AGV placed (nonstrabismus)			.7[b]
Superotemporal	72%	84%	
Superonasal	17%	10%	
Inferotemporal	3%	4%	
Inferonasal	7%	2%	
Follow-Up After AGV surgery, y, mean ± SD	3.1 ± 1.6	3.0 ± 2.0	.7[a]
Visual acuity[c], logMAR, mean ± SD (range)			
Better-seeing eye	0.14 ± 0.25 (range: −0.125 to 0.875)	0.45 ± 0.75 (range: −0.125 to 3.1)	<.0001[a]
Worse-seeing eye	0.96 ± 0.98 (range: 0 to 3.1)	1.60 ± 1.26 (range: 0 to 3.4)	<.0001[a]
Eye with AGV	0.81 ± 0.94 (range: 0 to 3.4)	1.27 ± 1.17 (range: 0 to 3.1)	.002[a]

AGV = Ahmed glaucoma valve, logMAR = logarithm of the minimum angle of resolution.

[a]Welch *t* test.

[b]χ^2 test.

[c]For visual acuities recorded as "count fingers," "hand motion," "light perception," and "no light perception," the following logMAR values were used, respectively 2.6, 2.9, 3.1, and 3.4.[4]

METHODS

THIS STUDY WAS APPROVED BY THE UNIVERSITY OF CALIfornia, Los Angeles Institutional Review Board and complied with the US Health Insurance Portability and Accountability Act of 1996. The list of all patients undergoing implantation of an AGV was obtained for procedures between March 2013 (the initiation of our electronic medical record) and July 2018. In general, over the 5-year period, our group has used the S2, FP7, and S3 models. We reviewed the records of every patient, including all histories, physical examinations, operative reports, and referrals. Patients who complained of persistent binocular diplopia or strabismus were included in the "strabismus" group. Patients with monocular diplopia were not included. Similarly, patients who were noted to have new-onset strabismus or motility disturbance by the treating physician regardless of whether the patient had subjective complaints were also included in the "strabismus" group. Patients who had preoperative strabismus diplopia or were monocular were excluded. Patients without subjective or objective findings of strabismus at any of their ophthalmology appointments were categorized as the "nonstrabismus" group. Patients were excluded if they had other glaucoma drainage devices implanted in addition to their AGV(s), prior or subsequent scleral buckles, or brachytherapy plaques. If a patient had a second AGV or another glaucoma implant placed after their first AGV, they were only analyzed for the purpose of this study in the interim period between their first AGV and immediately prior to their second glaucoma device surgery.

The following data were recorded from the chart: patient age, sex, location of AGV(s), subjective sensorimotor complaints including diplopia or abnormal motility, follow-up duration, visual acuity, and ocular alignment in 5 cardinal positions of gaze. All patients with strabismus or diplopia underwent a full examination by a pediatric ophthalmologist with expertise in strabismus. During this examination, patients were tested with cover-uncover and alternate cover testing in all 5 cardinal positions of gaze at distance and at near. For patients who were unable to hold fixation or with visual acuity worse than 20/200, ocular alignment measurements were done using the Krimsky test. Statistical analysis was performed using IBM SPSS Statistics, version 17.0 (SPSS Inc, Chicago, Illinois, USA). Groups were compared using a Welch *t* test for continuous variables and a χ^2 test for categorical variables.

RESULTS

A TOTAL OF 732 CHARTS OF PATIENTS WHO UNDERWENT AGV implantations were reviewed. Of those 732 patients, 29 (4%) patients developed strabismus that persisted beyond 6 months after initial AGV implantation and all of them were evaluated by the Strabismus service at our institution.

The 29 patients who developed strabismus were compared with those who did not (n = 703; Table 1). The mean age of strabismic patients was significantly lower than the others (46±29 years vs 65±21 years, respectively; $P < .0001$).

TABLE 2. Location of Ahmed Valve and Type of Strabismus

	Location of Ahmed Valve			
	Superotemporal (n = 21)	Superonasal (n = 5)	Inferotemporal (n = 1)	Inferonasal (n = 2)
Exotropia	8 (38)	2 (40)	1 (100)	
Esotropia	2 (9)	1 (20)		
Hypertropia >5 PD	4 (19)			
Hypotropia >5 PD	1 (5)	1 (20)		
Combined esotropia, hypotropia	1 (5)			
Combined exotropia, hypertropia	5 (24)	1 (20)		2 (100)

Values are n (%).

The follow-up duration was similar in the strabismus and nonstrabismus groups (3.1±1.6 years vs 3±2 years, respectively, $P = .7$). Mean visual acuity in both the better- and worse-seeing eye was better in the patients with strabismus than in the others ($P < .0001$).

A majority of AGVs were implanted superotemporally in both groups (72% in the strabismus group vs 84% in the others; $P = .7$). The AGVs were implanted superotemporally in 21, superonasally in 5, inferotemporally in 1, and inferonasally in 2. Twenty-one strabismic patients (72%) had diplopia. In both the superotemporal and superonasal AGV groups, strabismus was most commonly exotropia. Eleven patients (38%) were exotropic (mean deviation 19±18 PD, range 4-55 PD), 3 were esotropic (10%, mean deviation 9±6 PD, range 4-16 PD), 4 (14%) had ipsilateral hypertropia (mean deviation 4±3 PD, range 1-8 PD), 2 (7%) had ipsilateral hypotropia (mean deviation 5.5±3.5 PD, range 3-8 PD), and 9 (31%) patients had both horizontal and vertical deviations exceeding 5 PD (mean horizontal deviation 28±15 PD, range 10-60 PD; mean vertical deviation 14±6 PD, range 6-25 PD). One patient had esotropia with ipsilateral hypotropia, and 8 had exotropia with ipsilateral hypertropia. Superotemporal AGVs were more commonly associated with ipsilateral hypertropia, whereas superonasal AGVs were more equally distributed with ipsilateral hypertropia and hypotropia (Table 2).

Fifty-one patients were aged <18 years, and 9 of these had strabismus (18%). Of these children, the most common strabismus was exotropia (4/9) and exotropia with ipsilateral hypertropia (3/9). One child had combined esotropia with ipsilateral hypotropia, another had esotropia with ipsilateral hypertropia.

DISCUSSION

IN OUR LARGE SINGLE-CENTER POPULATION OVER A 5-YEAR period, the incidence of persistent strabismus after AGV implantation was at least 4%. Despite previous studies estimating the rate of strabismus and diplopia after glaucoma drainage device implantation, this study is the largest to focus specifically on patients undergoing implantation of the Ahmed device and included a review of all 732 charts of consecutive patients undergoing the procedure over a 5-year period in an attempt to define the true rate of this complication.

The AGV was introduced to the market in 1993.[5] Our group has used the S2, FP7, and S3 models. The AGV was initially recommended as a valved device with a lower risk of post-operative hypotony than available alternatives.[6] In addition, the plate of the AGV (model S2 and FP7) was smaller (184 mm^2) than the commonly used Baerveldt 101-350 (350 mm^2). The Baerveldt was thought to induce restrictive strabismus mainly because of its bulk prior to redesign that added fenestration and reduced bulk of the plate, and more recent fenestrated models have a lower rate of strabismus than the older, nonfenestrated models.

In their initial experience involving 60 patients undergoing AGV implantation, Coleman and associates[6] reported a 5% rate of diplopia 3 months postoperatively. Since then, others have reported rates of strabismus ranging from 0 to 4.7%.[6,7] Huang and associates reported the results of 159 eyes in a multicenter retrospective case series, and found 3% incidence of new-onset motility disorders. In 85 subjects with advanced glaucoma, Ayyala and associates found a 4.7% incidence postoperative diplopia. However, none of these studies reported the patterns of the strabismus or attempted to evaluate how AGV location influenced strabismus patterns in affected patients.

The overall incidence of strabismus in our case series is compared to previous case series in Table 3. AGVs also have been studied within larger randomized trials. For example, in the Ahmed Baerveldt Comparison Study, 276 patients were randomized to undergo implantation of either an Ahmed FP7 or Baerveldt 101-350 device.[3] In this study, both groups had similarly high 5-year incidence

TABLE 3. Previous Studies Evaluating the Incidence of Strabismus or Diplopia After Ahmed Glaucoma Valve

Authors (Date)	Study Type	No. of Patients	Rate of Strabismus, %	Rate of Diplopia, %
Coleman et al (1995)[5]	Prospective clinical trial	60	NR	5
Ayyala et al (1998)[7]	Retrospective case series	85	NR	4.7
Huang et al (1999)[6]	Retrospective case series	144	2.8	NR
Budenz et al (2016)[3]	Prospective randomized trial	143	NR	12.7
Christakis et al (2016)[4]	Prospective randomized trial	124	5.0[a]	
Current study	Retrospective case series	732	4	2.9

NR = not reported.
[a]Persistent diplopia *or* motility disturbance.

rates of persistent diplopia (12.7% vs 11.8% for the AGV and Baerveldt groups, respectively). In the Ahmed vs Baerveldt Study, the 5-year incidence of persistent diplopia or a motility disorder was lower, occurring in 6 patients (5%) in the Ahmed group and 2 patients (2%) in the Baerveldt group.[4] However, specific motility findings and influence of device location was not addressed in either of these studies as they were focused on glaucoma outcomes.

Other glaucoma drainage devices have been studied more frequently than the AGV in large groups to determine the incidence of motility disturbance. In the multicenter randomized Tube vs Trabeculectomy Study, new motility disturbances were detected in 5% of the 101 subjects who underwent implantation of the Baerveldt 101-350 glaucoma implant, but none in the trabeculectomy group at 1-year, and 6% vs 2% at 5-year follow-up.[1,2] Most recently, in the Primary Tube vs Trabeculectomy Study followed for 3 years, 6% of patients undergoing Baerveldt 101-350 implantation complained of diplopia compared to 3% after trabeculectomy.[8] Therefore, the range of new-onset diplopia or motility disturbance after Baerveldt implantation is similar (5%-6%) to that of AGV as determined by our study (at least 4%). Other smaller studies of the Baerveldt implant have retrospectively reviewed between 30 and 182 subjects and reported a rate of diplopia ranging from 1.4% to 37%.[2,9–14]

In 2017, Sun and associates[15] enrolled 195 glaucoma patients in a prospective study that assessed the presence of diplopia using the previously developed Diplopia Questionnaire.[16] In this series, 47 of the patients underwent glaucoma drainage device surgery (Baerveldt n = 35 and AGV n = 16), and 11 (23%) of them subsequently experienced new-onset diplopia postoperatively. The majority of these patients had superotemporal implantation (10/11 subjects) of a single Baerveldt device (7/11 subjects). Only 2 of the 11 subjects had AGVs. The authors of this study point out that the overall frequency of diplopia in their entire cohort of glaucoma patients (surgical and nonsurgical) was 21% and state that other studies may underestimate the rate of diplopia in this population because of the lack of standardized questionnaires and motility examinations in many of the previously reported large studies. In addition, the authors point out that strabismus was more common in patients undergoing surgery with the larger Baerveldt-350 than with the Baerveldt 250 or the AGV.[16]

The underlying etiology of strabismus after implantation of any glaucoma drainage device can be due to mass effect, restriction induced by the implant or fat adherence, scarring of the muscle, or displacement of the muscle path.[15,17,18] A large encapsulation can limit movement toward the implant, whereas scarring and contracture can pull the eye toward the implant. Furthermore, it can be exacerbated by advanced glaucomatous visual field loss. Interestingly, there was a higher rate of strabismus in patients who were younger and had better visual acuity. We hypothesize that younger patients (less than 40 years old) with healthier eyes may have a higher risk of reactive scarring because of thicker Tenon's capsule and a stronger lateral rectus-superior rectus bands, or may be more sensitive to notice diplopia because of their overall better visual acuity in the better and worse eyes and subsequently mention their strabismus to their surgeon. Interestingly, after exotropia, the second-most common form of strabismus in patients with superotemporal valve placement was combined exotropia and hypertropia, whereas patients with superonasal valve placements had either hypertropia or hypotropia. This finding highlights a possible underlying mechanism of strabismus as a mechanical tightening of the superior rectus and/or associated connective tissue in superotemporal valve placements, whereas superonasal valves may also cause a mechanical Brown syndrome from a tightened superior oblique, or a simple mass effect from the nasally situated valve where there may be less space compared with other quadrants. In superotemporal AGV placements, a large majority of patients had exotropia, ipsilateral hypertropia, or a combination of them. This reveals that scarring and contracture are probably a more common cause of strabismus in these patients, as opposed to a mechanical obstruction toward movement in the direction of the AGV placement. It is uncertain if other designs of glaucoma drainage devices have similar findings—a question that deserves further exploration.

This study must be understood within the context of its limitations. Despite its large sample size, the study was retrospective and relied on chart review to determine whether a patient complained of diplopia or strabismus, or whether any related finding was noted on examination. However, this study is also powerful in that it included a thorough chart review of every patient who underwent surgery for an AGV, thereby producing a reliable estimate of incidence compared with reliance on claims coding. It is possible that a patient with strabismus may have been missed if they did not complain of strabismus or diplopia, and their glaucoma specialist did not find it on their motility examination; therefore, the 4% estimate may be an underestimate. In light of its limitations, this study provides an estimate of motility disturbances in a large cohort of patients undergoing implantation of an AGV. The incidence is similar to the reported incidence of motility disturbance in similarly large studies that have evaluated the Baerveldt glaucoma device. In this cohort, the most common forms of strabismus were exotropia and hypertropia, and strabismus was more common in younger subjects as well as those with better visual acuity. These risk factors should be considered and discussed with patients undergoing implantation of an AGV.

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