GONIOSURGERY FOR PREVENTION OF ANIRIDIC GLAUCOMA*

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ABSTRACT

Purpose: We conducted a retrospective study to report the long-term success and complications of modified goniosurgery to prevent aniridic glaucoma, an entity that typically is difficult to control medically or surgically.

Methods: Fifty-five eyes in 33 patients who had aniridia without glaucoma and who had goniosurgery were identified. Ninety-one procedures were performed on 55 eyes by 1 surgeon (D.S.W.). Each eye had an average of 1.65 procedures and an average of 200 degrees of goniosurgery. Average patient age at time of initial goniosurgery was 37 months. There were no operative complications.

Results: No eye had a decrease in visual acuity at last follow-up. All eyes had a preoperative intraocular pressure (IOP) of less than 21 mm Hg. At last follow-up (average, 9 years 6 months; range, 8 months to 24 years), 49 eyes (89%) had IOP of less than 22 mm Hg without medications. The remaining 6 eyes (11%) had IOP of less than or equal to 22 mm Hg with up to 2 eye drops. Of 224 aniridic eyes of 112 patients that were seen for eye care by 1 of the authors (D.S.W.), 119 eyes (53%) demonstrated glaucoma, as defined by IOP of greater than 21 mm Hg.

Conclusions: Without prophylactic goniotomy, aniridic glaucoma may be expected in half of patients, and when it occurs, it is extremely difficult to control. Prophylactic goniosurgery in selected eyes of young patients with aniridia is effective in preventing aniridic glaucoma.

INTRODUCTION

Aniridia is a rare hereditary ocular disorder typically characterized by iris hypoplasia and the risk for glaucoma. This condition may show autosomal dominant transmission or be sporadic. Other clinical manifestations of

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aniridia may include decreased vision, cataracts, and nystagmus. Decreased vision can occur secondary to corneal opacities, cataracts, ectopia lentis, foveal and optic nerve hypoplasia, and glaucoma.

Although congenital glaucoma is rare, the incidence of glaucoma in late childhood or early adulthood ranges from 6% to 75%.[1] The development of glaucoma has been attributed to progressive changes in the angle ocurring during the first 2 decades of life.[2,3] The most common course of glaucomatous angle progression includes increased confluence of irregular attachments from the iris stroma onto the angle wall. These attachments migrate forward to obscure the scleral spur and posterior trabecular meshwork. This may be accompanied by tilting of the iris from the normal plane perpendicular to the axis of the eye to a plane parallel to the axis of the eye (Fig 1).[3] Other possible mechanisms of increased intraocular pressure (IOP) may include absence of Schlemm's canal[1] or secondary angle closure following miotic therapy.[4]

Once glaucoma develops, medical therapy may prove inadequate.[3,5] Surgical therapy, which also has an uncertain prognosis, has included argon laser trabeculoplasty,[1] goniotomy,[6,7] trabeculotomy,[5] filtering procedures (trabeculectomy and full-thickness filters),[7,8] and cyclocryotherapy.[8]

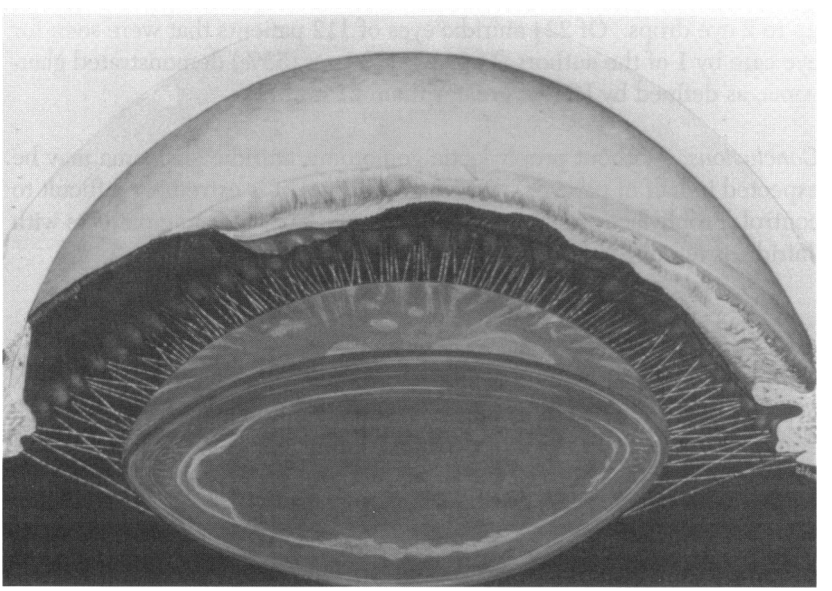

FIGURE 1
Progressive angle changes in aniridic glaucoma.

Other techniques, such as trabeculotomy[9] or Molteno implants[10,11] or internal sclerectomy with an automated trephine,[12] may have more potential for success.

Because of the progressive nature of the angle changes associated with worsening glaucoma and because of the difficulties of medical and surgical treatment in advanced stages of glaucoma, a prophylactic modified goniosurgery described by Grant and Walton[3,7] has been performed to prevent glaucoma in those eyes showing early glaucomatous angle changes. This prophylactic surgery detaches the abnormal extensions of iris stroma from the angle wall.

In the present study, we report the long-term results in aniridia patients who have received prophylactic goniosurgery.

PATIENTS AND METHODS

We retrospectively reviewed all records of patients with aniridia who were seen by one of us (D.S.W.) from 1971 to 1997. These records included those who had undergone prophylactic modified goniotomy as well as those who had not.

For all patients, IOP at time of initial presentation was recorded. For patients who had prophylactic goniosurgery, the following information was reviewed: age at surgery, preoperative and postoperative IOP, corneal diameter, visual acuity, length of postoperative follow-up, complications, and gonioscopic observations.

Exclusion and inclusion criteria for prophylactic goniosurgery were as follows. Because of the normal shallow anterior chamber present during the first year of life, surgery was avoided during this interval. Office gonioscopy and Perkins tonometry, however, began during this period for patients examined during their first year. After 1 year of age, gonioscopic abnormalities dictated the recommendation for surgery. When office examination produced uncertain observations, examination under general anesthesia was performed. If the trabecular meshwork was found unobstructed for greater than half of its circumference, no surgery was recommended. If, however, covering of the posterior trabecular meshwork by apparent extensions of tissue from the peripheral iris was present for more than half of its circumference, then surgery was recommended. Anterior progression over time of peripheral iris tissue onto the trabecular meshwork also was an indication for prophylactic goniotomy. Patients were excluded from this study of the results of prophylactic surgery if their IOP was greater than 21 mm Hg.

Preoperative and postoperative office IOP measurements were recorded from examinations using a Perkins tonometer, with patients unsedated.

Under general anesthesia and prior to prophylactic goniotomies, all patients underwent Schiotz tonometry, anterior segment examination, and funduscopy by direct ophthalmoscopy. A hand-held microscope and light source were used for Koeppe gonioscopy. All prophylactic modified goniotomies were done by 1 surgeon (D.S.W.) with the same technique, which is described in the next section.

Success was defined as IOP maintained at less than 22 mm Hg without medications. Control was defined as IOP less than or equal to 22 mm Hg with medications. Failure was defined as IOP greater than 22 mm Hg despite medications or as occurring when further surgery was needed. The postoperative course as well as repeated gonioscopy were described.

Poor fixation or cooperation precluded adequate visual field examination in most of our patients.

SURGICAL TECHNIQUE

All surgeries were performed with patients under general endotracheal anesthesia. Goniotomies were done with an operating gonioscopy lens, loupes, and a nontapered knife. The eye was pretreated with 1 drop of atropine sulfate 0.5% to produce cycloplegia and prevent rotation of the iris stroma anteriorly and with 1 drop of apraclonidine 0.5% to decrease postsurgical bleeding.

The globe was entered nasally and temporally. The operating lens was smaller than that usually used in nonaniridic patients with larger corneas to allow easy entry through peripheral clear cornea. The initial direction of entry was slightly more posterior than is customary to avoid a lengthy corneal passage. Rotation of the globe by the assistant during the procedure allowed for a larger arc of surgery to be performed.

The tip of the gonioscopy knife engaged the abnormal tissue extending anteriorly over the trabecular meshwork. Gentle pressure posteriorly initiated removal of this tissue off the meshwork. Although such tissue was frequently vascularized with visible red vessels, bleeding was not encountered. Posterior movements of the knife tip continued as the blade was rotated circumferentially. After approximately 3 clock hours were completed, the knife was returned to the starting meridian and was used to sweep the sulcus that was just created to eliminate any persistent iridotrabecular attachments. The operation was then continued for the full extent of the angle that could be easily visualized. The knife was then removed, and the anterior chamber was re-formed with balanced saline solution. The eye was usually inspected 6 and 24 hours after surgery. A final administration of atropine sulfate 0.5% was given on the first morning following surgery.

The prophylactic procedure departs from the technique of goniotomy

for glaucoma by intentionally avoiding injury to the trabecular tissue. In contrast, when goniotomy is done for treatment of aniridic glaucoma, a cleft is produced in the trabecular tissue.

RESULTS

Chart review revealed 145 patients with aniridia. Of these patients, 112 were seen for eye care and did not have prophylactic goniosurgery. The other 33 patients had prophylactic goniosurgery in at least 1 eye (Fig 2). Of the 112 patients (224 eyes) that did not have prophylactic goniosurgery, 119 eyes (53%) had glaucoma and 105 eyes (47%) did not. Glaucoma was defined as IOP greater than 21 mm Hg.

Of the 33 patients who did not have glaucoma, 55 aniridic eyes met the inclusion criteria for prophylactic goniosurgery. All patients preoperatively had IOPs lower than 21 mm Hg without glaucoma medications. Mean age at time of initial prophylactic goniosurgery was 36.6 months (range, 10 months to 113 months). There were 18 male and 15 female patients.

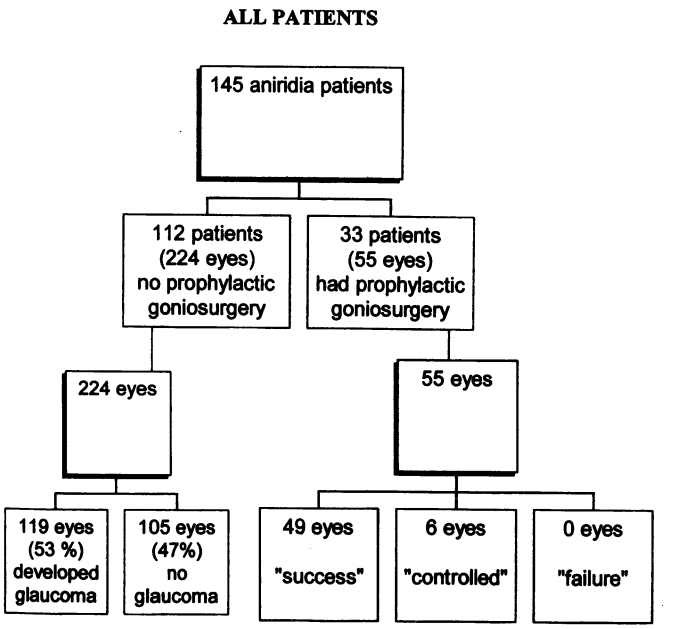

FIGURE 2
Results in all aniridia patients in this study.

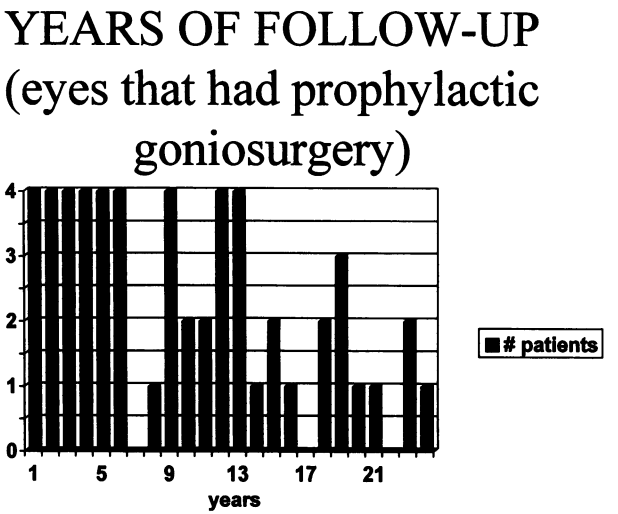

FIGURE 3
Years of follow-up in eyes that had prophylactic goniosurgery (average, 9 years and 6 months).

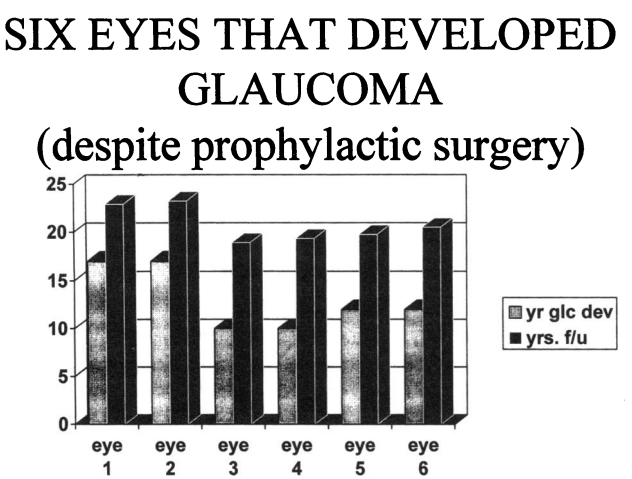

FIGURE 4
Six eyes that developed glaucoma despite prophylactic goniosurgery. Key: yr glc dev = year glaucoma developed; yrs f/u = years of follow-up.

Twenty patients showed autosomal dominant inheritance, and 13 patients showed sporadic inheritance. Eleven of the 55 eyes were myopic, with an average spherical equivalent of -2.23 diopters.

Ninety-one procedures were performed on 55 eyes by 1 surgeon (D.S.W.) for the 33 patients. Nineteen eyes had 1 procedure done, and 36 eyes had 2 procedures done. Each eye had an average of 200° of goniosurgery. Average age at time of initial goniosurgery was 37 months. There were no operative complications. The follow-up range was 8 months to 24 years. Average follow-up was 9 years and 6 months (Fig 3).

At last follow-up, 49 eyes (89%) had IOP of less than 22 mm Hg without medications and were, therefore, *successful* (Fig 2). The remaining 6 eyes (11%) of 3 patients had IOP of less than or equal to 22 mm Hg with one or two glaucoma topical medications and were, therefore, *controlled* (Figs 2 and 4). There were no *failures* (Fig 2).

No eye that had prophylactic goniosurgery had a decrease in visual acuity at last follow-up.

DISCUSSION

The reported incidence of glaucoma in aniridia varies from 6% to 75%,[1] but the approximate risk of glaucoma is generally conceded to be 50%. In our series, 53% of aniridic patients had glaucoma at their initial consultation.

The mechanism of aniridic glaucoma is often related to progressive angle changes that occur during the first decade of life. Glaucoma usually presents in childhood or early adulthood and does not typically present with enlarged corneas or myopia. Aniridic glaucoma in infancy is uncommon and has been associated with abnormalities of Schlemm's canal or angle function.[8] The angles of these young patients typically do not show progressive angle changes.

Once glaucoma develops, patients often become refractory to medical therapy.[3,13]

Surgical management of aniridic glaucoma is difficult. Blake[14] reviewed the experiences of 41 ophthalmologists who had operated on aniridic glaucoma patients, however, and concluded that there was no convincing opinion as to the best surgical treatment. Results of argon laser trabeculoplasty (ALT) have been unsatisfactory. Spaeth, who attempted treating 4 cases with ALT, noted inadequate IOP lowering.[1] Wiggins and Tomey[8] reported 2 cases of unsuccessful treatment with ALT.

Goniotomy has also been tried for the treatment of aniridic glaucoma. Barkan[15] reported a case of successful goniotomy at 9 months follow-up. Grant and Walton[3] reported 12 eyes that had therapeutic goniotomy. Although 9 eyes showed greater responsiveness to medical treatment after

goniosurgery, no cure could be claimed for any of these procedures. Walton[7] later reported 14 other eyes that had therapeutic goniotomy, and only 2 eyes (14%) had successful IOP control. Low rates of success with goniotomy were also noted by Adachi and associates,[9] who reported a success rate of 20% (1 in 5 eyes).

Trabeculectomy may also be disappointing. Spaeth noted that 5 of 14 patients either needed reoperation or failed with primary trabeculectomy.[1] Wiggins and Tomey[8] noted only a 9% success rate. Grant and Walton[3] reported 9 eyes in 7 patients whose glaucoma was not successfully controlled with filtering operations. Adachi and colleagues[9] reported 5 eyes that underwent initial trabeculectomy and 2 eyes that underwent initial Scheie procedure. Although none of the eyes were successfully treated with 1 operation, 4 of the eyes were eventually successfully treated with repeated filtering surgery.

Cyclocryotherapy does not show significantly better results. Only 1 of 2 eyes showed benefit with cyclocryotreatment in one study,[3] and only 25% of patients in another study achieved IOP control with cyclocryotherapy.[8] Adachi and colleagues[9] reported 6 eyes receiving a total of 17 cyclodestructive surgeries, and only 1 surgery succeeded. In addition, 3 of the eyes became phthisical. Wallace and coworkers[16] reported 7 eyes that were primarily treated with cyclocryotherapy. Although 6 of the 9 procedures that were performed on these eyes achieved IOP control, only 3 of 7 procedures had long-term visual stability. Because of the significant rate of phthisis and loss of vision with cyclocryotherapy, this cannot be recommended as a primary procedure for aniridic glaucoma. Strasser[17] suggested that argon laser cyclophotocoagulation may even accelerate the preexisting tendency of tissue proliferation within the anterior chamber angle.

Molteno and associates[10] reported 3 aniridic eyes with glaucoma that achieved a pressure of less than 20 mm Hg without medications after Molteno implantation. Billson and colleagues[11] used a 2-stage Molteno implant, which lowered IOP to less than 21 mm Hg in 2 eyes in 1 patient with aniridia. Wiggins and Tomey[8] reported successful IOP control in 83% of 6 eyes. Although the success rate of Molteno implant surgery is favorable, most investigators do not recommend this as an initial procedure because of the higher potential for complications.[8,9]

Wiggins and Tomey[8] noted that both trabeculotomies performed in their study were unsuccessful. Trabeculotomy, however, has been suggested as the preferred initial operation for uncontrolled glaucoma with aniridia.[9] In a report of 12 eyes, 10 eyes (83%) obtained IOP control after first (6 eyes) or second (4 eyes) trabeculotomy with a mean follow-up of 9.5 years.[9] If only eyes that had IOP controlled without medications were counted as surgical successes, only 25% (3 eyes) of the 12 eyes were successful. These investigators[9] also concurred with previous reports that

eyes treated with goniotomy, trabeculectomy, Scheie's procedure, or Molteno implant have lower rates of surgical success, since only 3 (18%) of these 17 eyes were controlled with the first glaucoma surgery.[9] Trabeculotomy was possibly more successful in these patients, because these eyes were in young patients (average age, 4 years 9 months) who, in general, did not show progressive angle changes. Of the 9 eyes that had had gonioscopy, only 1 eye showed trabecular meshwork that was covered with iris stump. All other eyes showed either no angle closure or a small, low iris residual. Of the 2 eyes that failed initial trabeculotomy, 1 eye was noted to have the later onset type of glaucoma associated with progressive angle changes.

Therefore, a review of the literature of the surgical treatment of aniridic glaucoma reports poor control of IOP with ALT, goniotomy, and trabeculectomy. Although cyclocryotherapy and Molteno implants may also be used, their higher rates of complications make these treatments a poor choice for initial therapy. Because aniridic glaucoma is difficult to treat surgically, we propose a prophylactic goniosurgery that decreases the risk of glaucoma in selected aniridic patients with progressive angle changes.

Following recognition of the acquired angle defect in aniridia consisting of blockage of the trabecular meshwork with tissue extending anteriorly from the iris, this abnormality was associated with the presence of glaucoma complicating aniridia.[3] At the suggestion of Drs Chandler, Grant, and Johnson, a program of prophylactic goniosurgery was initiated for young aniridic patients without glaucoma, and the favorable initial results in 16 children were reported.[7] This care has continued, and this report describes the results of this effort to lessen the risk of glaucoma in young aniridic patients.

New patients seen for care most frequently come to our office either at an early age for consultation in regard to the diagnosis and care of aniridia or later in childhood with glaucoma resistant to medical therapy. Patients with glaucoma consistently demonstrate obstruction of the trabecular meshwork with an abnormal iris-like tissue circumferentially.

When a young child is seen, the program of careful observation is initiated, including tonometry and gonioscopy. During the first year of life, office Koeppe gonioscopy is done. This technique provides useful information regarding the condition of the trabecular meshwork and approximation of the iris. During the first 18 months of life, the anterior chamber progressively deepens, which facilitates goniosurgery when necessary. Although office Koeppe gonioscopy is informative, it most often does not permit adequate magnification of angle structures to detect significant progression of nonpigmented tissue over the posterior trabecular meshwork. After the first year of life, regular examinations under general anes-

thesia are performed to assess the filtration angle conditions. Depending on the findings, such examinations are repeated every 3 to 9 months. A final decision for goniosurgery may be made at the time of such an examination.

On gonioscopy, striking circumferential asymmetry is often present. The superior angle is usually most affected, but goniosurgery has not been done superiorly, since findings there have not dictated surgery. In any patient, the nasal or temporal angles may be quite different. Surgery is done only in those nasal, temporal, or inferior quadrants where an obstructive angle abnormality is present. Typically, the defect seen is a slender net of tissue extending anteriorly from the iris to the midtrabecular meshwork. Initially, this tissue is scalloped anteriorly, but in time it thickens and becomes more uniform along its anterior extremity. Fine vessels are inconsistently seen at more solid points of attachment to the trabecular meshwork. These extend anteriorly onto the trabecular meshwork, then turn and follow the circumferential edge of this cover over the posterior meshwork tissue. Branching of these vessels does not occur (Fig 1).

The technique of prophylactic goniosurgery for aniridia has been previously described and has been consistent for all patients.[7] The goal of surgery is to engage the abnormal tissue on the trabecular meshwork and strip it posteriorly while the knife point is moved circumferentially. The anatomic result of this technique is to produce a permanent separation between the iris and filtration tissue. Reattachment or revascularization onto the trabecular tissue does not occur. Reflux of blood into the anterior chamber after surgery is minimal. Inspection of an eye 6 and 24 hours after surgery reveals little evidence of any procedure. When compared with the fellow eye, some shallowing of the anterior chamber is commonly observed.

CONCLUSIONS

Selected aniridic eyes with early progressive angle changes that had had prophylactic goniosurgery demonstrated a significantly lessened risk for glaucoma. There were no failures of IOP control. Aniridic glaucoma is difficult to control with medical treatment, trabeculotomy, goniotomy, and trabeculectomy. Surgical treatment with cyclocryotherapy and Molteno implants is associated with high complication rates. Trabeculotomy or even goniotomy[7] may be helpful in young aniridic patients with glaucoma with no angle closure or only a small, low iris residual. Prophylactic goniosurgery for selected young children with progressive angle changes is effective in preventing or delaying the onset of aniridic glaucoma. Without prophylactic goniosurgery, aniridic glaucoma may be expected in half of affected children and is extremely difficult to control.

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DISCUSSION

DR PAUL R. LICHTER. It is more than commendable that the authors have continued to inform us of the apparent efficacy of a treatment that Dr Morton Grant and Dr Walton first described at the 1974 American Ophthalmological Society (AOS) meeting to prevent so-called aniridic glaucoma. The fact that a careful and thoughtful clinician continues to pursue the treatment after having performed it first over a quarter century ago is reason to pay close attention to the information. In discussing Dr Walton's 1986 AOS paper on this subject, Dr Douglas Anderson raised appropriate skepticism as to how one knows that the goniosurgery advocated here actually prevents glaucoma and that a clinical trial would be the

appropriate way to find out.

But aniridia is a rare disorder and the glaucoma associated with it is seen in only half the cases at most. And since Dr Walton is so convinced that it works, it would not be ethical for him to randomize his patients. Therefore, surgeons who might participate in a clinical trial would need to periodically carefully assess the angle as Dr Walton does and, where indicated, perform the technically difficult surgery — surgery that they have not performed previously. I am inclined to accept Dr Walton's clinical judgment that this surgery works in selected patients. But I think it may be fair to say, as he implies, that half the patients on whom Dr Walton is operating would not develop intractable glaucoma if the surgery were not done. So I would like to turn my discussion toward the disease called "aniridia" and to the way we might approach the disease based on current information in medical and molecular genetics. In essence, I want to ask you to consider 4 questions: (1) Why do only some patients with aniridia develop glaucoma? (2) Why do only some patients with aniridia develop the clinical signs of angle abnormalities that Dr Walton treats with goniosurgery? (3) Why does the goniosurgery prevent glaucoma? and (4) Is there a way to predict which patients with aniridia will develop glaucoma and thereby possibly benefit from this goniosurgery?

To review the patient population in the authors' study, there were 145 records reviewed of patients with aniridia presenting for eye care, of whom 112 did not have prophylactic goniosurgery. Fifty-three per cent of these eyes had glaucoma and 47% did not. Of the remaining 33 patients, there were 55 eyes that met the authors' criteria for goniosurgery. This leads us to our first question.

Why do only some patients with aniridia develop glaucoma? Aniridia is a complex disorder caused by mutations in PAX6, a homeodomain — or homeobox — gene, located on chromosome 11p13. The aniridia gene is called AN2 because it was thought that there was another gene — designated AN1 in 1980 — which also caused aniridia. But this was later refuted, so that there is actually only one known aniridia gene, and it is designated as AN2. In a review of PAX6 mutations published earlier this year, Prosser and Heyningen catalogued 44 mutations in exons. This accounts for much of the enormous variability in the phenotypic characteristics of the aniridic syndrome as seen clinically. Embryologic animal research suggests that the PAX6 gene may regulate neural crest cell migration from the anterior midbrain. Because homeobox genes are fundamental to basic embryologic development, mutations in them can cause a variety of clinical defects that, depending on the specific mutation, can range widely in severity and extent. Interestingly, PAX6 appears to be critical in pancreatic islet development. So, while this gene's function is not confined to the eye, its effects on the eye can range from minimal to extensive. For exam-

ple, patients with PAX6 mutations may have a variety of iris defects, ranging from those that are barely detectable to those that manifest nearly total absence of the iris. Similarly, patients with aniridia may or may not have glaucoma, foveal dysplasia, optic nerve hypoplasia, nystagmus, corneal dystrophy, Peter's anomaly, and/or cataract. PAX6 can seemingly be involved in a spectrum of anterior segment disorders, depending on the mutation in the gene. It would be of great interest for the authors to review their cases to carefully characterize the phenotypes in their patients and to determine the mutation each patient carries. Relating the DNA data to the phenotype would almost certainly shed light on which of the aniridia mutations are associated with glaucoma and which ones are not.

Why do only some patients with aniridia develop the clinical signs of angle abnormalities that Dr Walton treats with goniosurgery? If Dr Walton thoroughly characterizes the ocular and associated systemic phenotypes of his patients, he will be able to correlate the phenotypes with the DNA data. Hopefully, he can then determine which mutations are associated with the very specific gonioscopic findings he describes as being a major risk factor for the development of glaucoma in his patients. Interestingly, of the 33 patients who qualified for goniosurgery, 13 were sporadic cases and 20 had an autosomal dominant form of inheritance. What about the inheritance pattern in the other 112 patients — the ones that did not have prophylactic goniosurgery? And what is the glaucoma history of the affected family members of the patients who had prophylactic goniosurgery?

Why does the goniosurgery prevent glaucoma? The developmental defects caused by one or more of the mutations in the PAX6 gene are resulting in clinically visible abnormal tissue that creeps onto the trabeculum. It is as if the trabeculum has an abnormal affinity for this tissue to grow onto it and thereby obstruct it. Apparently, Dr Walton's goniosurgery defeats this mechanism by stripping the tissue away from the trabeculum, and whatever caused the tissue to grow onto the trabeculum does not do so again. But until more is known about the specific protein defects that are produced by the PAX6 mutations, we will not know exactly why the goniosurgery prevents glaucoma.

It is worthwhile noting that since Dr Walton does not perform prophylactic goniosurgery on any patient under 1 year of age, other treatments were used on these younger patients. Might prophylactic goniosurgery help some of these as well? How can they be identified?

The definition of success after prophylactic goniosurgery is something with which to quibble. Since an intraocular pressure of at least 21 mm Hg was needed to qualify for prophylactic goniosurgery, and since "control" postoperatively was a pressure of 22 mm Hg or less with or without medication, a patient could have a higher intraocular pressure postoperatively than preoperatively and still be counted as "controlled."

Is there a way to predict which patients with aniridia will develop glaucoma and thereby possibly benefit from this goniosurgery? Even without DNA data, a clinician should evaluate the family of patients with aniridia. Since most aniridia is inherited as an autosomal dominant disorder, if family members with aniridia also have glaucoma, it is reasonable to assume that the patient has or will develop glaucoma too. But one third of aniridia cases are sporadic, so family phenotype is not always helpful.

In conclusion, I want to recall for Dr Walton a statement from his and Dr Grant's 1974 AOS paper on this subject: "We would like to understand the fundamental mechanism that is responsible for the progressive changes in the angle in aniridia that we have recognized clinically as the cause of the development of glaucoma in aniridia." This desire can be fulfilled with today's clinical and molecular genetic technology. In that regard, I have just 2 final questions for the authors:

1. Have they investigated the families of Dr Walton's patients to determine pedigrees and document the phenotype of affected and at-risk family members?

2. Have they studied the DNA of the patients to determine the mutations exhibited in the AN2 gene? I would be interested, of course, not only in the 20 autosomal dominant and 13 sporadic cases on whom Dr Walton operated, but in the other 112 patients who did not have prophylactic goniosurgery and in a comparison of the aniridia syndrome phenotypes of the patients and families with and without glaucoma.

We can look forward to the next report from Dr Walton — perhaps in 2010, continuing his every 12-year pattern — to include the medical genetic, DNA, and molecular biology data that will help clarify the relationship between the aniridia syndrome and its associated glaucoma.

TERESA CHEN, MD. First, I would like to thank Dr Lichter for his discussion and careful review of our paper.

The first question was why do patients with aniridia develop glaucoma. Drs Grant and Walton addressed this in their 1974 AOS thesis. Most patients with aniridia develop progressive angle changes during the first two decades. We feel that this is the most common cause of glaucoma. Prophylactic goniosurgery arrests these progressive angle changes and, therefore, can prevent glaucoma in these patients.

The second question was why do only some aniridia patients have progressive angle changes. All the patients that we saw with glaucoma had these progressive angle changes. It is possible that the other patients who did not have glaucoma and who did not have these angle changes were presenting at an earlier stage; perhaps some of these patients would later on develop progressive angle changes and glaucoma.

Dr Lichter also asked why the goniosurgery works. In his 1986 AOS

paper, Dr Walton noted that patients with progressive angle changes developed glaucoma. Therefore, by preventing or reversing the progressive angle changes, the goniosurgery prevents the development of glaucoma.

Dr Lichter also asked how we can predict which patients will develop glaucoma? Specifically, he asked if any pedigree or genetic studies were done. Clinically, we observed that the patients who had progressive angle changes were most likely to develop glaucoma. Correlations between genotypes and phenotypes were not the focus of this study. We did do genetic analysis in sporadic cases of aniridia to look for the chromosome 11p13 abnormality.

I would like to thank the AOS for the privilege of presenting this paper.