Goniosurgery for Glaucoma Complicating Chronic Childhood Uveitis

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Objectives: To describe the safety and efficacy of goniotomy in medically uncontrolled glaucoma complicating chronic uveitis and the factors affecting its outcome.

Methods: All goniotomies performed by a single surgeon for refractory childhood uveitic glaucoma were retrospectively reviewed. Success was defined as final intraocular pressure (IOP) of no greater than 21 mm Hg without medications and qualified success as IOP of no greater than 21 mm Hg with medications. Unless otherwise indicated, data are expressed as mean±SD.

Results: Fifty-four goniotomies were performed in 40 eyes of 31 patients. Juvenile rheumatoid arthritis–associated uveitis was the diagnosis in 30 eyes (75%). Eleven eyes (28%) were aphakic. Mean follow-up was 98.9 months (range, 2-324 months). Mean age at surgery was 10.3±4.7 years (range, 4-22 years). Mean preoperative IOP was 36.7±6.4 mm Hg while receiving a mean of 2.9±1.1 medications. Overall surgical success was achieved in 29 eyes (72%), including success in 22 (55%) and qualified success in 7 (18%) while receiving a mean of 1.6±1.1 medications. Mean postoperative IOP in the success and qualified-success groups were 14.3±2.8 and 15.7±3.1 mm Hg, respectively. Kaplan-Meier survival probabilities (95% confidence interval) at 1, 5, and 10 years were 0.92 (0.82-1.00), 0.81 (0.65-0.97), and 0.71 (0.49-0.92), respectively. Phakic eyes, eyes with fewer peripheral anterior synechiae, patients younger than 10 years, and eyes with no prior surgery had significantly better outcomes. Hyphema, typically mild and transient, occurred in 43 procedures (80%).

Conclusions: Goniosurgery is low risk and effective for refractory glaucoma complicating chronic childhood uveitis. It should be considered the surgical procedure of choice for this condition. Surgical outcome is adversely affected by increased age, peripheral anterior synechiae, prior surgeries, and aphakia.

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Veitis is a significant cause of secondary glaucoma in childhood, and the most common systemic association by far is juvenile rheumatoid arthritis (JRA). The overall prevalence of glaucoma in children with JRA-related uveitis has been estimated to be as high as 22%. Glaucoma complicating chronic childhood uveitis can result in significant visual impairment and is considered the most devastating complication of this disorder. Treatment of this secondary glaucoma is challenging because it is often refractory to medical and surgical therapies.

Existing surgical treatments that are most commonly chosen after failure of medical therapy include trabeculectomy and glaucoma drainage implants. The outcome of trabeculectomy in this group of patients is adversely affected by their young age, increased ocular inflammation, prolonged use of multiple topical drugs, and frequent need for cataract surgery, which all predispose to excessive fibrosis. Although the use of antimetabolites improves the success rate, they are associated with increased rates of complications such as bleb leaks, hypotony, and a lifelong risk of infection. Glaucoma drainage implants have been used with variable success and are also associated with serious vision-threatening complications such as corneal decompensation and retinal detachment and an increased need for surgical reinterventions. Hence, there is much room for improvement in the current surgical management of childhood uveitic glaucoma.

Goniotomy is the least invasive surgical procedure in the treatment of childhood glaucoma, which is an advantage in the treatment of uveitic eyes. However, the reported experience with standard goniotomy in the treatment of childhood uve-
tic glaucoma is limited. Haas\textsuperscript{19} first described the use of classic Barkan goniotomy in 3 patients with open-angle glaucoma associated with iridocyclitis in whom at least short-term control of intraocular pressure (IOP) was achieved. Trabeculodialysis, a modified goniotomy procedure in which the trabecular meshwork is disinserted from the scleral sulcus rather than simply incised as in conventional goniotomy, has been reported to have 44\% to 60\% success in the short term in small numbers of young patients with inflammatory glaucoma, especially in association with JRA.\textsuperscript{20,21} Freedman et al\textsuperscript{22} recently described the efficacy of conventional goniotomy in 12 patients with childhood uveitic glaucoma and found an overall success of 75\% with a mean follow-up of 32.4 months. Factors affecting the outcome of goniosurgery for this condition have not been previously described.

The aim of this report is to describe the long-term efficacy and safety of standard goniotomy for the treatment of glaucoma secondary to chronic childhood uveitis and the prognostic factors affecting its outcome in the largest known clinical series with the longest follow-up.

**METHODS**

We undertook a retrospective review of all medical records of patients for whom goniotomies were performed by a single surgeon (D.S.W.) for childhood uveitic glaucoma refractory to medical therapy. Goniotomy is the first-line surgical treatment after failed maximal medical therapy in this practice. Patients may have had prior surgeries, including cataract extraction and trabeculectomy, before referral to this practice for uncontrolled glaucoma. Uveitis was controlled with topical and/or systemic anti-inflammatory therapy as necessary until anterior chamber cells numbered less than 5 per high-power field using a 3\times1-mm slitlamp beam for at least 1 week before surgery in all eyes.

The main outcome measures were IOP at the last follow-up and time to surgical failure. A complete surgical success was defined as an IOP of no greater than 21 mm Hg without glaucoma medications at the final follow-up; qualified success, an IOP of no greater than 21 mm Hg with medications at the final follow-up; and failure, an IOP of greater than 21 mm Hg despite medical therapy. Overall success was used to indicate all cases in which success was complete or qualified. The secondary outcome measure was the number of medications needed to achieve an IOP of no greater than 21 mm Hg after surgery.

Intraocular pressures were measured using a Perkins tonometer in all eyes. Direct gonioscopy using a Koepe lens was performed in all eyes on the operating table before surgery and at least 2 weeks after goniosurgery whenever examination under topical anesthesia in the office setting was possible or under general anesthesia when a separate surgical procedure was required. The gonioscopic findings, including the number of clock hours of peripheral anterior synechiae (PAS), were recorded by means of detailed drawings in a goniogram at each examination.

Tonography was performed using the standard technique\textsuperscript{23} before and after goniotomy for the affected eye of an 11-year-old patient in the study who achieved complete success with an electronic indentation tonometer (V Mueller and Co, Chicago, Ill.). The indentation tonometer was used to measure the baseline IOP (P\textsubscript{0}) after instillation of topical anesthesia. A 4-minute pressure tracing was subsequently obtained with the needle recorder linked to the tonometer while it was gently applied to the cornea. Its position on the cornea was maintained until a smooth tracing for 4 minutes was obtained. The P\textsubscript{0} and the change in scale reading during the 4 minutes were then used to obtain the coefficient of outflow facility (C) from tonographic tables.\textsuperscript{24}

**GONIOTOMY TECHNIQUE**

All goniotomies were performed under general anesthesia using the standard goniotomy technique that has been previously described.\textsuperscript{24} Briefly, under direct visualization of the angle using a Barkan goniotomy lens, the anterior chamber was entered with a needle goniotomy knife through the peripheral clear cornea opposite the area of the angle to be treated. The knife was directed into the angle, and an incision was made in the posterior trabecular meshwork for 4 to 6 clock hours. The anterior chamber was then reformed with balanced salt solution instilled through the corneal incision, which was then closed with a 10-0 Vicryl (ETHICON Inc, Somerville, NJ) suture if leakage was observed. Postoperative topical antibiotics and steroids were administered. Topical steroid therapy was tapered to the preoperative frequency, usually within 2 weeks, according to the extent of anterior chamber inflammation observed. All preoperative systemic anti-inflammatory regimens were continued postoperatively. If a postoperative hyphema was observed, 0.5\% apraclonidine hydrochloride was given for 1 to 2 days after surgery to attempt to minimize it. Head elevation and avoidance of excessive crying, straining, or vigorous activity in the early postoperative period were recommended to reduce bleeding.

**STATISTICAL ANALYSIS**

Data were expressed as mean ± SD unless otherwise specified. We used the 2-tailed paired \( t \) test to compare preoperative and postoperative quantitative data and the McNemar \( \chi^2 \) test for related categorical data. Kaplan-Meier survival analysis was performed to calculate probabilities of overall surgical success at different time periods after surgery. We measured the association between surgical outcome and possible prognostic variables using the Pearson correlation for interval and ratio variables, \( \varphi \) for nominal variables, and Spearman \( \rho \) for ranked variables. We compared each of these variables between the different outcome groups using the \( \chi^2 \) test for categorical variables, \( t \) test for continuous variables, and Mann-Whitney U test for ranked variables. All statistical tests were 2 sided, and \( P \) values of less than .05 were considered significant. We used SPSS software, version 11.0 (SPSS Inc, Chicago, Ill) in the statistical analysis.

**RESULTS**

We included 40 eyes of 31 patients in this study. A total of 54 goniotomy procedures were performed. Twenty-eight eyes (70\%) underwent 1 goniotomy, 10 (25\%) underwent 2, and 2 (5\%) underwent 3. All except 7 patients were female. All patients were white except 1, who was Asian. The mean age at goniosurgery was 10.3±4.7 years (range, 4-22 years). Diagnoses included JRA-related uveitis in 30 eyes (75\%), idiopathic uveitis in 8 (20\%), and sarcoidosis in the remaining 2 (5\%). Twenty-nine eyes (72\%) were phakic, and 11 (28\%) eyes were aphakic at the time of surgery. Sixteen (35\%) of the phakic eyes had posterior subcapsular cataracts before surgery. The mean follow-up was slightly more than 8 years (98.9±87.8 months; range, 2-324 months). The mean preoperative IOP was 36.7±6.4 mm Hg, and the mean num-
The number of glaucoma medications used preoperatively was 2.9±1.1.

At the last follow-up, 22 eyes (55%) achieved surgical success without any glaucoma medications, and 7 eyes (18%), qualified success while receiving a mean of 1.6±1.1 medications. Failure occurred in 11 eyes (28%). This gave an overall success rate of 72% (in 29 eyes), which was achieved with a single goniotomy in 20 (69%) of these eyes. Postoperative mean IOP was 14.3±2.8 mm Hg in the complete-success group and 15.7±3.1 in the qualified-success group. Figure 1 compares the IOP and glaucoma medications preoperatively and postoperatively within the different surgical outcome groups. In eyes with overall surgical success, the mean IOP was reduced from 35.8±5.9 mm Hg to 14.7±2.9 mm Hg (P<.001), and the mean number of glaucoma medications was reduced from 3.0±1.2 to 0.4±0.9 (P<.001). The mean number of clock hours of PAS preoperatively was 1.6±2.6 compared with 3.1±2.5 postoperatively, indicating a significant increase in PAS extent after surgery (P<.001). There were no significant differences in the mean frequency of topical steroids used per day preoperatively and at the last postoperative follow-up in eyes with a successful outcome (2.1±1.8 and 1.6±1.7, respectively) or in eyes with failed surgery (2.2±1.5 and 1.8±1.5, respectively). There was also no statistically significant difference between the numbers of eyes that required steroids for uveitis control before surgery (29/40 eyes) and at the last follow-up after surgery (28/40 eyes).

The Kaplan-Meier survival plot for overall surgical success is shown in Figure 2. Mean cumulative survival probabilities (95% confidence interval) in all eyes with 1 or more goniotomies at the specified time intervals after surgery were as follows: 0.92 (0.82-1.00) at 1 year, 0.81 (0.65-0.97) at 5 years, 0.71 (0.49-0.92) at 10 years, and 0.56 (0.28-0.84) at 13 years, with no failure events occurring after 12 years (144 months). Beyond 12 years after the first goniotomy, 5 eyes were still being followed up and demonstrated surgical success at last follow-up.

Tonography performed in the affected eye of the 11-year-old boy with idiopathic uveitis who had complete success after a single goniotomy showed C values of 0.00 µL/min/mm Hg preoperatively at an IOP of 42 mm Hg.

Figure 1. A, Pregoniotomy and postgoniotomy intraocular pressure (IOP) in different outcome groups. B, Comparison of the numbers of preoperative and postoperative glaucoma medications.

Figure 2. Kaplan-Meier survival analysis of goniotomy success. The markers indicate censored eyes that experienced surgical success with or without medications at the last follow-up.
which increased to 0.07 µL/min/mm Hg postoperatively at an IOP of 18 mm Hg without glaucoma medications.

A statistically significant association was found between surgical outcome groups (success, qualified success, and failure) and lens status ($P = .004$), age at surgery ($P = .03$), number of past ocular surgeries ($P = .001$), and extent of preoperative ($P = .004$) and postoperative PAS ($P = .002$) in the angle. Phakic eyes had an overall success rate of 86% (25 eyes) compared with 36% (4 eyes) in aphakic eyes ($P = .004$) (Figure 3A). Patients 10 years or younger had a greater overall success of 79% (19 eyes) compared with 62% (10 eyes) for those older than 10 years ($P = .03$) (Figure 3B). Success was greatest in eyes without prior surgery (87%; 25 eyes), whereas eyes with more than 2 previous ocular surgeries before goniotomy such as cataract extraction or trabeculectomy had a uniformly poor outcome (100% failure) (Figure 4). The mean number of previous surgeries was $0.2 \pm 0.6$ in eyes with successful outcomes and $1.3 \pm 1.3$ in eyes with surgical failures ($P = .03$). Eyes with no PAS preoperatively had the highest success rate (82%), whereas those with more than 6 clock hours of PAS had a 100% failure rate. All eyes with no PAS at the last postoperative gonioscopy had operative successes. The mean number of clock hours of preoperative PAS and postoperative PAS was $0.9 \pm 1.5$ and $2.3 \pm 2.0$, respectively, in eyes with surgical success and $3.0 \pm 3.6$ and $4.8 \pm 2.9$, respectively, in eyes with surgical failure ($P = .01$ and $P = .007$ for preoperative and postoperative PAS, respectively). Figure 5 illustrates the relationship between preoperative and postoperative PAS and surgical outcomes.

Sex, diagnosis (type of uveitis), preoperative IOP, number of glaucoma medications before surgery, presence or severity of postoperative hyphema, frequency and use of topical steroids before or after surgery, and presence of persistent inflammation (defined as the persistent presence of cells or flare requiring topical steroids ≥3 times a day or the recurrent inflammation requiring increased topical steroids ≥3 times a day for more than 1 week within the last 6 months of follow-up) had no statistically significant correlation with the surgical outcome. Specifically, there was no difference in the surgical outcomes when comparing JRA-related uveitis with other types of uveitis as a group.

Hyphema occurred after 43 goniotomies (80%). This was mild and transient with complete spontaneous clear-
ance within a week in most affected eyes. In 2 eyes, an anterior chamber washout had to be performed for moderate hyphemas associated with elevated IOP. Deterioration of preexisting posterior subcapsular cataracts occurred early postoperatively in both eyes of a single patient requiring extraction at 1 and 4 months after surgery. Six other eyes required cataract extraction for progression of posterior subcapsular cataracts that existed before goniosurgery and became visually significant after goniosurgery (mean time after goniosurgery, 63.9 ± 57.2 months; range, 8-138 months). Of the 8 eyes that had cataract extraction after goniosurgery, 7 continued to have successful IOP control after that surgery (6 without need for glaucoma medications). In the remaining eye, cataract extraction was performed after 3 goniotomies that had resulted in successful IOP control without medications. In this eye, loss of IOP control occurred at 3.5 years after cataract extraction and was refractory to maximal medical therapy, necessitating a trabeculectomy with mitomycin. These progressive posterior subcapsular cataracts were most likely due to continued topical steroid use for the uveitis and were not likely to be related to the goniosurgery. No exacerbations of uveitis in the early postoperative period or other significant complications such as infection, iatrogenic damage to intraocular structures, hypotony, or posterior segment changes were encountered.

**COMMENT**

Secondary glaucoma is a frequent and serious complication of uveitis. In this largest known study to report the long-term results of standard goniotomy in childhood uveitic glaucoma, successful IOP control was achieved in 72% of eyes and in 55% without medications at the end of a mean follow-up of more than 8 years. Cumulative probabilities of overall success of goniosurgery at 1, 5, 10, and 13 years were 92%, 81%, 71%, and 56%, respectively. The only previous report on the subject by Freedman et al showed a similarly high overall success rate of 75% at a mean follow-up of 32.4 months, although most of their patients (75%) required glaucoma medications, and cumulative success probabilities were lower (79% at 1 year and 70% at 15 months). The difference was probably due in part to the smaller number of eyes and shorter follow-up. These results are exciting and suggest that goniotomy can improve the management of one of the most visually destructive and refractory forms of glaucoma in childhood and young adults.

Compared with the currently favored surgical options to increase aqueous outflow, standard goniotomy seems to have comparable or higher success rates but much fewer risks of complications. Success of trabeculectomy without antimetabolites in young patients or in eyes with inflammatory glaucoma is generally poor. Few published reports address the use of trabeculectomy for uveitic glaucoma in the young alone. Most include adult patients or other forms of pediatric glaucoma. Trabeculectomy with antimetabolites in adults with uveitic glaucoma have yielded cumulative success probabilities of 78% at 1 year and 62% at 2 years, although this is probably lower in children. Apart from the usual increased risks of hypotony, bleb leak, cataract formation, and bleb-related infection, there are further risks of complications associated with the uveitis such as postoperative fibrinous and cellular anterior chamber reaction, which can result in surgical failure. A histopathological study of conjunctival biopsy specimens from patients with uveitic glaucoma found that the uveitic conjunctiva contained significantly more fibroblasts, lymphocytes, and macrophages compared with that of controls, which may help explain the increased risk of bleb fibrosis and failure of filtration surgery in these
work. Significant outflow reduction can occur if angle closure is extensive or obliterates a previously functional goniotomy cleft. The mean number of clock hours of PAS in eyes with surgical failures in this series was 3 to 4 clock hours and was not markedly more extensive compared with eyes with surgical successes. This was because the surgical failures included eyes with open angles and other predispositions to failure such as aphakia or multiple prior surgeries. The effect of PAS on surgical outcome could best be illustrated in Figure 5, which shows that eyes with no PAS had the greatest likelihood of success, whereas eyes with extensive PAS of more than 6 clock hours had no chance of success (100% failure rate).

Older age, prior ocular surgery, and aphakia are probably associated with different or more advanced changes in the meshwork and/or more distal parts of the outflow system, which are less likely to be relieved by incisions in the meshwork by goniotomy alone, hence their association with adverse outcomes. Aphakia in young children is itself a definite risk factor for the development of glaucoma for reasons as yet unknown. These findings are in contrast to those of Kanski and McAllister on trabeculodialysis for inflammatory glaucoma in children and young adults, which found no association between aphakia or synechial angle-closure and outcome, and those of Freedman et al, which found no relation between age and crystalline lens status at surgery with surgical outcome. This may be due at least in part to the smaller sample size in these studies.

Cataract extraction after goniosurgery did not seem to compromise the surgical outcome in 7 (88%) of 8 eyes in this series. The only eye that experienced failure 3.5 years after cataract surgery also had other predictors of failure such as increased postoperative PAS (4 clock hours) and older age at surgery (21.5 years).

Use of topical steroids is known to cause IOP elevations. As the amount and presence of topical steroid use was not significantly different before and after goniosurgery, it is unlikely that the IOP reduction was due to reduction of steroid use with time.

Although goniotomy is widely recognized as an effective first-line surgery for primary congenital glaucoma, it also now deserves consideration as a relatively safe and effective first-line surgical treatment for medically uncontrolled glaucoma secondary to chronic childhood uveitis. Unlike filtration surgery, it is less traumatic, has fewer risks, and facilitates aqueous outflow through the normal drainage system of the eye rather than creating an artificial pathway that bypasses the physiological route. It is effective not only for JRA-related uveitis but also in idiopathic and sarcoid-related uveitis when the angle is open. Although the success rate of goniosurgery is highest in children 10 years or younger, older age up to young adulthood does not preclude success. Aphakia, multiple previous ocular surgeries, and extensive PAS are much stronger predictors of surgical failure.

In conclusion, goniosurgery is safe and effective for the treatment of glaucoma complicating chronic childhood uveitis. It should be considered the procedure of choice because it restores function of the trabecular tissue without bypassing it, is the least traumatic of the glaucoma surgeries, and spares the conjunctiva. Most treated patients. As a result, glaucoma drainage implants are often recommended for uveitic glaucoma. Various types of implants have been used with reported life-table success rates in adults of up to 94% (1 year), 90% (52 months), and 91.7% (24 months) for the Ahmed, Molteno, and Baerveldt implants, respectively, but this is variable, and relatively lower success rates of 57% to 76% have been found in other series. Vision-threatening complications such as choroidal effusion or hemorrhage, cataract, corneal decompensation, hypotony, and cystoid macular edema can occur, and surgical reinterventions for these or other complications such as encapsulated bleb, plate extrusion, corneal-tube touch, and flat anterior chamber are commonly required.

In contrast, goniotomy has very few complications, and these are limited almost exclusively to hyphemas in experienced hands in this study and that by Freedman et al. Due to the minimal invasion and manipulation of intraocular and extraocular tissues, exacerbation of uveitis did not occur in either study, and the conjunctiva of the eyes undergoing operation was spared for future filtration surgery if needed. Trabeculotomy ab externo, the alternative to goniotomy, has been used with a success rate comparable to that of goniotomy in the treatment of primary infantile glaucoma. However, its value in childhood uveitic glaucoma is unknown. Although widely regarded as a different means to the same end, it involves considerable conjunctival manipulation and is more traumatic than goniotomy. This may result in significant inflammation, which is undesirable and could affect its success rate in a uveitic eye.

Open-angle and closed-angle mechanisms play a role in the pathogenesis of glaucoma in uveitis, although the open-angle mechanisms are more common. Complex interactions between several biochemical and cellular mechanisms inherent in the inflammatory process occur to cause an elevation of IOP in the presence of an open angle. The success of goniotomy suggests that in many cases of glaucoma secondary to childhood uveitis, an incision in the inner portion of the meshwork where the angle is open reduces the resistance to aqueous outflow. The tonography results in the uveitic eye with uncontrolled glaucoma confirmed the preoperative reduction in outflow facility (C value of 0.00 µL/min per millimeters of mercury compared with a mean of 0.28 µL/min per millimeters of mercury for healthy eyes), which was increased but not normalized (C = 0.07 µL/min per millimeters of mercury) after goniotomy. The underlying mechanism for improved outflow facility is unclear. Goniotomy may result in a change of the cellular or biochemical milieu that reduces the outflow resistance. However, its long-lasting benefit, despite recurrent or persistent inflammation and the quantitative nature of its effect (more IOP lowering with additional or increased extent of goniotomy incision), suggests that a mechanical obstruction of aqueous outflow may exist in the inner portion of the meshwork that is reduced by the goniotomy incision. There was histopathological evidence of a persistent communication between the anterior chamber and the Schlemm canal in a specimen taken from an eye with sarcoid uveitis 1 month after trabeculodialysis. Closure of the angle by PAS formation before or after goniosurgery limits aqueous access to the meshwork.
patients do not require glaucoma medications after the procedure. Surgical success is higher in children younger than 10 years. Aphakia, multiple prior ocular surgeries, and extensive PAS are adverse prognostic factors for a successful surgical outcome.

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