Valved Glaucoma Drainage Devices in Pediatric Glaucoma
Retrospective Long-term Outcomes

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IMPORTANCE  Relatively little data exist about the long-term outcomes of an initial glaucoma drainage device (GDD) and subsequent GDDs implanted in pediatric patients with glaucoma.

OBJECTIVE  To determine the long-term outcomes of the first and second GDDs and risk factors in pediatric glaucoma.

DESIGN, SETTING, AND PARTICIPANTS  Retrospective review of 119 eyes of 89 patients younger than 18 years with glaucoma who underwent valved GDD implantation from March 1999 to April 2012 at the Stein Eye Institute, University of California, Los Angeles.

EXPOSURE  Implantation of GDD, using silicone and polypropylene Ahmed glaucoma valve.

MAIN OUTCOMES AND MEASURES  Kaplan-Meier survival analysis and risk factors associated with GDD failure. Success was defined as a final intraocular pressure of 5 to 21 mm Hg as well as a 20% reduction from baseline intraocular pressure with or without medications.

RESULTS  The mean (SD) age at implantation of the first GDD was 6.8 (5.7) years. The mean (SD) follow-up time was 6.1 (3.3) years from surgery. The mean intraocular pressure was reduced by 13.0 mm Hg (95% CI, 8.8 to 17.3 mm Hg) at 5 years postoperatively. The mean number of glaucoma medications preoperatively vs postoperatively was not different starting at 5 years (reduction of 0.5; 95% CI, −0.1 to 1.0). The success rate at 5 years was 55.0% (95% CI, 46.0% to 65.9%). Risk factor analysis suggests that older age (risk ratio = 0.95; 95% CI, 0.90 to 0.99; \( P = .02 \)), uveitic glaucoma (risk ratio = 0.34; 95% CI, 0.14 to 0.86; \( P = .02 \)), and polypropylene GDDs (risk ratio = 0.39; 95% CI, 0.23 to 0.67; \( P = .001 \)) were associated with higher success rates.

CONCLUSIONS AND RELEVANCE  Glaucoma drainage devices, such as the Ahmed glaucoma valve, have moderate long-term success rates in pediatric patients with glaucoma. In pediatric patients, the first GDD is successful in 46% to 70% of patients at 5 years with medications, and the second GDD is successful in 37% to 75% of patients at 5 years after the subsequent surgery.

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Valved Implant Glaucoma Drainage Devices in Pediatric Glaucoma

Pediatric glaucoma is a heterogeneous group of uncommon diseases that can lead to optic nerve damage and blindness. Its appropriate diagnosis and treatment are particularly important when considering the number of years these patients may live with their visual disability. Previous studies suggest that a favorable prognosis depends on early diagnosis and suitably aggressive treatment to reduce intraocular pressure (IOP). While some patients can be managed with medications, surgery is often the preferred method of treatment given the overall poor success rate of glaucoma medications in children.1

Anterior chamber angle surgical procedures, such as goniotomy and trabeculectomy, have a good initial success rate in patients with primary congenital glaucoma. However, the initial procedure may not adequately control the IOP, and additional surgery may be required to prevent progressive nerve damage. Patients with secondary glaucomas may not respond to angle surgery.2 Currently, there is no widely accepted surgical algorithm after failure of angle surgery, and a variety of approaches have been used, including trabeculectomy with and without adjunctive antimetabolites, glaucoma drainage devices (GDDs), and cycloablative therapy. Glaucoma drainage devices are associated with a higher rate of reoperation and a greater need for postoperative glaucoma medications compared with the other 2 procedures, but they have the advantage of fewer vision-compromising complications and an acceptable level of IOP control.2,3 They have success rates ranging from 30% to 90% depending on the duration of follow-up and the specific diagnosis studied.4-10 The purpose of this study is to evaluate the long-term outcomes of polypropylene and silicone Ahmed glaucoma valve (AGV) implants (New World Medical Inc) and risk factors for success in pediatric patients with glaucoma.

Methods

This is a retrospective study of 119 eyes of 89 consecutive patients who underwent AGV implantation from March 1999 to April 2012 at the Stein Eye Institute, University of California, Los Angeles, with a minimum of 1 year of follow-up. All patients were younger than 18 years at the time of their first GDD surgery with no prior aqueous shunt surgery. Patients were divided by diagnosis into 3 subgroups: primary glaucoma, uveitic glaucoma, and secondary glaucoma. Primary glaucoma included both congenital and juvenile glaucoma. Uveitic glaucoma included patients with any type of uveitis, although most had juvenile idiopathic arthritis. Secondary glaucoma consisted of pediatric patients with any other diagnosis, as follows: anterior segment dysgenesis, phakomatoses, retinopathy of prematurity, previous cataract surgery, steroid-induced diagnosis, and trauma. Institutional review board approval from the University of California, Los Angeles was obtained for this study, and all methods adhered to Health Insurance Portability and Accountability Act of 1996 regulations and the Declaration of Helsinki. The requirement for informed consent was waived owing to the retrospective nature of the study.

At a Glance

- Relatively little data exist about the long-term outcomes of an initial glaucoma drainage device and subsequent glaucoma drainage devices implanted in pediatric patients with glaucoma.
- Ahmed glaucoma valves have moderate long-term success rates in pediatric patients with glaucoma.
- In patients younger than 18 years, these retrospective data suggest 46% to 70% success of the first Ahmed glaucoma valve at 5 years with medications and 37% to 75% success at 5 years after second surgery.

GDD Implantation, Success, and Failure

Silicone and polypropylene single-plate GDDs (models FP-7 and S-2, respectively) were implanted by 4 experienced surgeons with similar technique in the superotemporal or superonasal quadrants, with the tube in the anterior chamber. The surgical technique for GDD implantation has previously been described.10 The decision of which GDD to use was not based on patient characteristics; surgeons consistently used silicone or polypropylene GDDs. Examinations under anesthesia were performed when an adequate ophthalmic examination could not be performed in the office. Glaucoma medications were added postoperatively at the discretion of the physician to maintain satisfactory IOP control. Success was defined as a final IOP of 5 to 21 mm Hg as well as a 20% reduction from baseline IOP with or without medications. Final IOP was the average of all IOP measurements during the last 6 months of follow-up. If the eye did not have at least 2 measurements in this period, 2 measurements from the most recent visits were used to calculate the average. Failure was defined as a final IOP outside the aforementioned range, additional glaucoma surgery, or development of any serious complications, including removal of the implant, endophthalmitis, loss of light perception, hypotony maculopathy, and phthisis bulbi. Revisions of the GDD (usually re-covering of the tube because of exposure near the limbus) were not included as a failure criterion. Patients suspected to have strabismus who noted diplopia underwent cover testing.

Statistical Analysis

Kruskal-Wallis testing was used to evaluate differences in patient characteristics between different diagnoses and GDD model subgroups. Kaplan-Meier survival analyses and the log-rank test were used to evaluate success and the difference in success rates among diagnostic groups. Fisher exact test was used when comparing categorical variables. Cox regression analysis with a cluster model to account for pairs of eyes was used to evaluate the association between the duration of success and predictive factors for failure. Predictive factors of interest were age at the time of diagnosis and surgery, sex, ethnicity, diagnosis, preoperative IOP, and prior number of glaucoma operations. A P value cutoff of .20 was used to choose the covariates to include in the multivariate Cox regression. All statistical analyses were performed in R statistical software version 0.98.932 with the survival package (R Core Team). P < .05 was considered statistically significant.
Results

Patient Characteristics

Table 1 describes the patient characteristics. The mean (SD) follow-up for all eyes was 6.1 (3.3) years from surgery (range, 1.0-14.2 years). Most GDDs (112 [94.1%]) were implanted in the superotemporal quadrant, and the remaining were implanted in the superonasal quadrant. The mean (SD) age at implantation of the first GDD was 6.8 (5.7) years. The average age at implantation for the eyes receiving a silicone GDD (mean [SD], 4.7 [5.0] years) was younger than that for the eyes receiving a polypropylene GDD (mean [SD], 7.7 [6.0] years) (P = .007). The duration of follow-up was also shorter for eyes with a silicone GDD (P = .006). The distribution of diagnoses was not statistically significant by Fisher exact test (P = .24).

The mean (SD) IOP was reduced from 29.2 (9.7) mm Hg preoperatively to 15.2 (3.5) mm Hg at 10 years (P < .001). The mean number of medications was 2.2 (1.3) preoperatively and was no longer different at 5 years postoperatively (reduction of 0.5; 95% CI, −0.1 to 1.0). Between those who received a silicone GDD and those who received a polypropylene GDD, the IOP and number of medications after surgery were not different (P = .21 and .12, respectively) (eFigure in the Supplement).

Survival

The success rates for all eyes were 85.7% (95% CI, 79.7%-92.2%) at 1 year and 36.8% (95% CI, 26.8%-50.4%) at 10 years (Figure). The success rate at 5 years was 55.0% (95% CI, 46.0%-65.9%). Because of the decreasing number of eyes with long follow-up, the 5-year survival values are reported for the separate diagnoses. The success rate at 5 years was 41.8% (95% CI, 26.5%-66.0%) for eyes with primary glaucoma, 75.0% (95% CI, 57.7%-97.5%) for uveitic eyes, and 53.9% (95% CI, 41.8%-69.4%) for eyes with other secondary glaucoma. The success rates among the types of glaucoma were not different by log-rank test (P = .06). At 5 years, the survival of eyes with polypropylene implants was 66.9% (95% CI, 55.4%-80.9%) compared with 41.2% (95% CI, 28.5%-66.9%) for eyes with silicone implants (P < .001) (Figure).

GDD Failure

Table 2 lists the reasons for failure. The eye that lost light perception had a diagnosis of Norrie disease, and loss of vision was attributed to the retinal process rather than to glaucoma. No eyes had a final IOP lower than 5 mm Hg. There was no difference regarding the reason for failure between the 2 types of implants (Fisher exact test, P = .23). Eyes of patients younger than 2 years at the time of initial surgery were found to have a higher rate of undergoing additional GDD implantation compared with those aged 8 years or older at the time of initial surgery (log-rank test, P = .047).
having a risk ratio of 0.45 (95% CI, 0.24-0.86; \( P < .02 \)) was the main risk factor, with eyes receiving a polypropylene GDD associated with higher success rates. Other complications were not statistically compared owing to the small number of events. Complications were not associated with a specific diagnosis or GDD model (Fisher exact test, \( P > .29 \)).

**Risk Factors**

In univariate Cox regression, GDD model, age at implantation, and diagnosis were all found to be risk factors for failure (Table 3). Risk factor analysis suggests that older age (risk ratio = 0.95; 95% CI, 0.90-0.99; \( P = .02 \)), uveitic glaucoma (risk ratio = 0.34; 95% CI, 0.14-0.86; \( P = .02 \)), and polypropylene GDDs (risk ratio = 0.39; 95% CI, 0.23-0.67; \( P = .001 \)) were associated with higher success rates. Similar results were observed in a repeated analysis performed with a cluster analysis to account for pairs of eyes. In the subgroup analysis of eyes that received a polypropylene GDD, eyes with uveitic glaucoma and secondary glaucoma had a lower risk ratio than those with primary glaucoma; however, this trend was not seen in eyes with silicone GDDs. For a more detailed description of the subgroup analysis, refer to eTable 1 in the Supplement.

A multivariate Cox regression with a cluster model to account for pairs of eyes was performed with covariates with \( P < .20 \) on univariate analysis: age at the time of surgery, diagnosis, ethnicity, and GDD model. Only implant model remained a risk factor, with eyes receiving a polypropylene GDD having a risk ratio of 0.45 (95% CI, 0.24-0.86; \( P = .02 \)) (Table 3).

**Overall Complications**

Tube revision, which occurred in 26 eyes (21.8%), was the most common surgical intervention after GDD implantation; of those, tube exposure was the most common reason for revision (9 eyes [7.6%]). Four eyes (3.4%) underwent tube revision for tubes touching the cornea, but none of these eyes had stromal edema or required penetrating keratoplasty. Five eyes (4.2%) required cataract surgery for visually significant cataract that developed after implantation of the GDD. Three eyes (2.5%) required strabismus surgery after GDD implantation. eTable 2 in the Supplement shows the rate of tube complications. Other complications were not statistically compared owing to the small number of events. Complications were not associated with a specific diagnosis or GDD model (Fisher exact test, \( P > .29 \)).

**Subsequent GDD Implantation**

For the 36 eyes that received a second GDD, the mean (SD) time between GDD implantations was 2.2 (1.6) years. Fifteen (41.7%) were diagnosed as having primary congenital glaucoma, 4 (11.1%) as having uveitic glaucoma, and 17 (47.2%) as having other secondary glaucomas. The success rate for the second GDD was 52.8% (95% CI, 37.0%-75.3%) at 5 years. The time to median survival was 6.5 years. The most common reason for failure of the second GDD was the requirement for additional glaucoma surgery. Eight eyes (22.2%) received an additional GDD for IOP control, 3 eyes (8.3%) had removal of a GDD, and 1 eye (2.8%) underwent cyclophotocoagulation. The previously mentioned risk factors were not found to affect the likelihood of failure with Cox regression (\( P > .38 \)). The most common complication was cataract formation, which occurred in 9 eyes (25.0%). Three eyes (8.3%) underwent cataract extraction. Strabismus was noted in 5 eyes (13.9%), and 2 (5.6%) required surgery.

**Discussion**

In pediatric patients with glaucoma, the success rates after GDD surgery were 85.7% after 1 year and 55.0% after 5 years. Age, diagnosis, and GDD model were found to influence success rates. Older age at GDD implantation, a diagnosis of uveitic glaucoma, and polypropylene GDDs were associated with higher survival rates. Most patients eventually required medications to adequately control IOP. Eyes implanted with a subsequent GDD had a 52.8% success rate at 5 years after the second surgery.

Success rates after 1 GDD in this study are consistent with those reported in the literature, which range from 63% to 93% after 1 year and 30% to 70% after 5 years. \(^3\)\(^-\)\(^10\) Eyes diagnosed as having primary glaucoma had a lower success rate than eyes with other diagnoses. Ou et al\(^10\) and Djodey et al\(^7\) also found a lower success rate in eyes with congenital glaucoma, although it was statistically significant only in the latter study. In contrast, O’Malley Schlothoefer et al\(^19\) reported no differences in success between eyes with aphakic glaucoma and eyes with congenital glaucoma receiving an AGV. Eyes diagnosed as having uveitis had a higher success rate than eyes with other diagnoses. The few studies that have addressed AGV implantation in pediatric uveitis have reported high success rates in this subset of patients. One reported 100% success in 7 eyes.
risk factor. To our knowledge, no other study has reported an association between age and the probability of success, although younger eyes had a lower success rate. Only 1 other study, which included both pediatric and adult eyes and used Baerveldt GDDs, found age to be a risk factor for surgical failure, with younger eyes having a lower success rate. Only 1 other study, which included both pediatric and adult eyes and used Baerveldt GDDs, found age to be a risk factor for surgical failure, with younger eyes having a lower success rate.

A longer time to median survival than those receiving silicone GDDs. In contrast, previous studies in adult eyes comparing silicone and polypropylene GDDs suggested similar, if not better, success rates with silicone GDDs. To our knowledge, comparisons between AGVs in pediatric patients are limited to 2 studies, which showed better survival with silicone valves. Although silicone GDDs were implanted at an earlier age than polypropylene GDDs, age was not a risk factor in the silicone GDD subgroup. Furthermore, the shorter follow-up for eyes with silicone GDDs would also not influence the observed difference in success rates. The survival probability consistently remained higher for eyes with polypropylene GDDs at all times, and it is unlikely that longer follow-up for eyes with silicone GDDs would increase survival. The higher success rates with the polypropylene GDDs were observed in only the uveitic and other secondary glaucoma subgroups. Pediatric studies that show improved survival with silicone GDDs have been conducted predominantly in patients with congenital glaucoma, which could explain the difference in survival between the silicone and polypropylene valves observed in this study compared with those of other studies. Furthermore, the silicone implant contains small fenestrations that allow for tissue ingrowth and a smaller bleb compared with the polypropylene model, which does not have the fenestrations; this difference in design could affect success rates. Additional research would be required to further elucidate the influence of the GDD model has on outcomes in pediatric patients.

The need for an additional GDD was the most common reason for failure in our series. Similarly, Ou et al reported a second GDD as the reason for failure in most eyes. In the small subset of eyes that underwent a second GDD implantation, success rates were similar to those of the first GDD but the incidence of complications was higher.

A number of complications were encountered in this series of pediatric glaucomas. Similar to previous reports, tube exposure was the most common cause for reoperation. Strabismus surgery was required in 2.5% of eyes that underwent GDD implantation in this study. This rate is similar to that in other studies that have reported strabismus rates of 3% to 11%. Permanent strabismus after drainage device implantation is a less frequent but serious complication. The complexity of strabismus surgery after glaucoma drainage valve implantation, an appropriately sized valve should be used and ocular muscles identified and spared during device placement.

In this study, 5 cases of cataract requiring extraction were attributed to the shunt. Previous studies in pediatric patients report cataract development after shunt surgery in up to 20% of patients. In this study, no tubes were noted to be in contact with the lens during examination, but transient tube touch during eye rubbing could have contributed to cataract formation. Numerous factors other than tube positioning, including metabolic alteration of the aqueous and the use of ocular medications, may also play a role in development of visually significant cataracts. Finally, a major concern with GDDs is corneal decompensation, especially in younger eyes. Four eyes in this series

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<th>Table 3: Risk Factors for Surgical Failure After Implantation of a GDD in Pediatric Patients With Glaucoma</th>
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<td>Risk Factor</td>
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<td><strong>Univariate analysis</strong></td>
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<td>Other</td>
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<td>Polypropylene GDD&lt;sup&gt;b&lt;/sup&gt;</td>
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Abbreviations: GDD, glaucoma drainage device; IOP, intraocular pressure.
<sup>a</sup> Reference group was males.
<sup>b</sup> Reference group was silicone GDDs.

with 3 years of follow-up, and the other reported 80% success in 5 eyes with approximately 2.7 years of follow-up. More work will be required to elucidate the reasons for these apparently high success rates.

Age at the time of shunt implantation was found to influence the likelihood of failure, with younger eyes having a lower success rate. Only 1 other study, which included both pediatric and adult eyes and used Baerveldt GDDs, found age to be a risk factor. To our knowledge, no other study has reported an association between age and the probability of success, although there may not have been sufficient numbers of patients to detect a difference. Age at diagnosis was similar to that observed with age at implantation; however, the age at diagnosis was not always available. Because of the inconsistency of the date of diagnosis, we opted to report age at surgery. Age may play a role because of the earlier presentation of patients with congenital glaucoma as well as increased complications seen in younger patients due to a more poorly developed outflow pathway, eye rubbing, and difficulty maintaining a medication regimen. Furthermore, decreasing eye dimensions after controlling the IOP of young patients or increasing eye size during growth can cause tube complications related to movement and malpositioning.
were found to have tube-corneal touch; however, none of them required penetrating keratoplasty during follow-up.

This study is limited by its retrospective nature and lack of a predetermined follow-up schedule. Because the study was performed at a tertiary care center, some patients continued their care elsewhere after surgery and were lost to follow-up. Visual acuity and visual fields were not regularly assessed because patients were not always able to cooperate with the examination owing to their age and systemic diseases. Strengths include a large sample size with a relatively long follow-up and uniformity of treatment in pediatric patients. This study also included all types of pediatric glaucoma, which allows for comparisons between diagnostic groups.

Conclusions

We report moderate long-term success with GDDs (AGVs) in pediatric patients with glaucoma. Given the relatively low rate of serious complications, the AGV, which can be implanted in multiple quadrants, is a viable solution. For pediatric patients who may require lifetime IOP control, the first GDD is successful in 46% to 70% of patients at 5 years with medications, and the subsequent GDD is successful in 37% to 75% of patients at 5 years after the second surgery. The results of this study will help guide decision making to preserve vision in a group of patients with a challenging disease.

REFERENCES