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CLINICAL STUDY

Clinical outcomes after Ahmed valve implantation in refractory paediatric glaucoma

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Abstract

Purpose **To evaluate clinical outcomes after Ahmed valve implantation in refractory paediatric glaucoma.**

Methods **A retrospective review was conducted on 34 eyes from 29 patients with refractory glaucoma, who were younger than 18 years of age and who underwent Ahmed valve implantation. The main outcome measures were intraocular pressures (IOPs) and the number of glaucoma medications used. Qualified success was defined as IOP $\leqslant$21 mm Hg regardless of the number of glaucoma medications. Complete success was defined as IOP $\leqslant$21 mm Hg without glaucoma medication.**

Results **Mean age at operation was 5.5 years (range, 0–16). Fifteen eyes (44.1%) had undergone previous glaucoma surgery before Ahmed valve implantation. Mean follow-up time was 29.1 months (range, 3–31). IOP was reduced from a preoperative mean of 37.5 $\pm$ 7.3 to 18.4 $\pm$ 7.3 mm Hg at 6 months postoperatively ($P<0.01$). At 12 months after surgery, the success rates were 63.3% (qualified success) and 13.3% (complete success). The cumulative probabilities of qualified success at 6, 12, and 24 months after Ahmed valve implantation were 89.0, 68.6, and 45.7%, respectively. The median time of survival was 19.6 $\pm$ 0.9 months.**

Conclusions **Ahmed valve implantation is effective in lowering IOP in refractory paediatric glaucoma, with limited survival after long-term follow-up. Addition of a second Ahmed valve may be effective in the management of failure after primary implantation.**

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Keywords: Ahmed valve implantation; glaucoma drainage device; intraocular pressure; paediatric glaucoma

Introduction

In paediatric glaucoma, the mainstay of treatment is surgical management,[1,2] whereas medical management is used adjunctively to reduce intraocular pressures (IOPs).[3–7] Goniotomy and trabeculotomy were initially considered for congenital glaucoma, with comparable results.[8–11] Viscotrabeculotomy, using viscoelastic material during trabeculotomy, may increase success rates through prevention of both postoperative haemorrhage and adhesion of the incision lips.[12,13] Trabeculectomy also shows encouraging results, and may be supplemented by mitomycin C or combined with trabeculotomy.[14–18] However, overall success rates after paediatric glaucoma surgery range from 60 to 92%, with the rates declining over time. Furthermore, some paediatric glaucoma respond poorly to goniotomy or trabeculectomy.[8,19] Cycloablative therapy can be considered in refractory cases, but success rates are limited with a higher risk of complications.[20–22]

Glaucoma drainage devices are widely used in the treatment of refractory paediatric glaucoma, especially when filtering surgery has failed or is known to have a high risk of failure, such as significant conjunctival scarring.[23,24] The first glaucoma drainage device used in the paediatric population was the Molteno implant (IOP Inc., Costa Mesa, CA, USA),[25] followed by the Baerveldt implant (Pharmacia and Upjohn Inc., Kalamazoo, MI, USA)[23,26,27] and Ahmed valve implant (New World Medical Inc., Rancho Cucamonga, CA, USA).[23] The Ahmed valve

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implant has a protective sleeve, which is designed to open when the aqueous pressure is higher than 8 mm Hg. This is highly effective in reducing the risk of early postoperative hypotony compared to the Molteno and Baerveldt implants, which do not have sleeves. Several reports of Ahmed valve implantation (AVI) used in refractory paediatric glaucoma show comparable results to AVI in adults and implantation of other drainage devices.[28–34] This study was conducted to evaluate the efficacy, complications, and risk factors for failure after AVI in paediatric glaucoma patients who were refractory to medical treatment or other surgical procedures.

Materials and methods

We retrospectively reviewed the medical charts of patients younger than 18-year-old, who had uncontrolled IOP despite medical therapy or previous glaucoma surgeries, and who underwent AVI performed by a single glaucoma surgeon (KHP) between July 2002 and July 2007 at Seoul National University Children's Hospital. The minimum required follow-up period after surgery was 6 months. The study was conducted under Institutional Review Board (IRB) approval.

The preoperative clinical data obtained for each patient included the patient's age at diagnosis, age at the time of surgery, gender, specific type of glaucoma diagnosis, history of other ocular or systemic disease, ocular trauma or surgery, anterior segment findings, posterior segment findings, IOP, number of glaucoma medications, and visual fields, if possible. All IOPs were measured by Tono-pen (Mentor, Norwell, MA, USA), Goldmann applanation tonometer, or Perkins applanation tonometer.

Patients were examined postoperatively at 1 day, 1 week, 1 month, 3 months, and 6 months, then every 3 months depending on the patient's clinical status. The IOP and number of glaucoma medications were noted at all examinations. Follow-up visits also included slit-lamp examination for evaluation of corneal clarity, tube position and patency, anterior segment inflammation, lens status, tube and scleral patch coverage, and bleb appearance. Quantitative visual acuity measurements were obtained whenever possible, and dilated indirect and direct ophthalmoscopy was performed periodically, with notation of any vitreoretinal pathology.

Ahmed valves designed for children (model S-3) were used for patients 12-year-old or under ($n=31$). The standard-sized plates (model S-2) were used for patients older than 12-year-old ($n=3$; 8.7%). Model S-3 is smaller than the standard S-2. Although the tube length (25.0 mm) and internal, external diameters (0.305, 0.635 mm) are equivalent, the valve width (9.6 mm; S-3 *vs* 13.0 mm; S-2) and length (10.0 *vs* 16.0 mm) are shorter in the paediatric model, and the surface area is half the size of the adult model (96.0 *vs* 184.0 mm^2).

The surgical procedure for AVI is as follows: a fornix-based conjunctival incision was created in the superior temporal quadrant or superior nasal area (in cases in which the temporal quadrant was previously operated). After the sclera was exposed, a partial thickness limbal-based scleral flap was cut in a rectangular shape. The tube was primed using balanced salt solution, and the Ahmed drainage plate was tucked under the subconjunctival space and sutured to the underlying sclera with its anterior edge 6–8 mm posterior to the limbus, using two 8-0 nylon anchoring sutures.

To decrease the risk of early postoperative hypotony, partial ligation of the tube was accomplished by the method described by Dr Kee, using 6–0 polypropylene (Prolene; Ethicon Ltd., UK) as a stent by locating it beside the tube, ligating both the tube and the stent with 8–0 polyglactin (Vicryl; Ethicon Ltd.), and then withdrawing the stent.[35] The tube was trimmed bevel up so that it reached the mid-iris. A 23-gauge needle was used to enter the anterior chamber at the surgical limbus under the scleral flap, aiming toward the centre of the pupil. The tube was inserted through this opening, and no additional suture was made to secure the tube to the sclera. The partial thickness scleral flap covered the tube and was sutured to the sclera posteriorly using 8–0 polyglactin (Vicryl; Ethicon Ltd.). The conjunctiva was sutured using 8–0 polyglactin (Vicryl; Ethicon Ltd.) at the anterior edge of the conjunctival flap, so that the scleral patch was completely covered. A subconjunctival injection of dexamethasone was given. Postoperatively, topical antibiotics, steroid drops (usually in a combination), and atropine were prescribed, all of which were slowly tapered over the course of 4–8 weeks.

The primary outcome measures were IOP and the number of glaucoma medications used at each period. Qualified success was defined as IOP $\leqslant$21 mm Hg regardless of the number of glaucoma medications. Complete success was defined as IOP $\leqslant$21 mm Hg without glaucoma medication. Cases with visually significant complications were considered failures. Success rates after AVI was evaluated at each follow-up period.

Statistical analyses were performed using SPSS for Windows (version 15.0, Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL, USA). Postoperative IOP and number of glaucoma medications were compared with preoperative values using the paired Student's *t*-test and Wilcoxon signed rank test. Univariate analysis of risk factors for failure in different subgroups was made using Pearson's χ^2-test or Fisher's exact test. The cumulative probability of success was examined by Kaplan–Meier

life table. A P-value of <0.05 was considered statistically significant.

Results

The clinical characteristics of the patients are summarized in Table 1. A total of 34 eyes of 29 patients were enrolled in this study. Mean age at operation was 5.5 ± 4.2 (range, 0–16) years and mean follow-up period was 29.1 ± 16.2 (range, 6–63) months. Five (17.2%) patients underwent bilateral AVI. The indications for AVI are shown in Table 1.

In total, 15 eyes (44.1%) had undergone previous glaucoma surgery prior to AVI, including trabeculotomy in 11 eyes (32.4%), trabeculectomy with antimetabolites in 13 eyes (38.2%), cyclophotocoagulation in 4 eyes (11.8%), and previous implant (Molteno) in 1 eye (2.9%). The mean number of prior glaucoma surgeries performed on each eye was 1.1 ± 1.4 (range, 0–4). The number of eyes that underwent previous glaucoma surgeries was distributed as follows: one surgery ($n=2$; 5.9%), two surgeries ($n=6$; 17.7%), three surgeries ($n=4$; 11.8%), four surgeries ($n=3$; 8.8%). The diagnosis of the 15 eyes that underwent secondary AVI were: congenital glaucoma ($n=10$), aphakic glaucoma ($n=1$; who had undergone filtering surgeries in another institution), anterior segment dysgenesis (mild forms of Axenfeld–Rieger anomaly or aniridia; $n=3$), and Down syndrome ($n=1$).

Table 1 Patients' demographic data

Total patients	29
Total eyes	34
Gender	
Male	18 (62.1%)
Female	11 (37.9%)
Bilaterality of glaucoma	
Bilateral	16 (55.2%)
Unilateral	13 (44.8%)
Age at diagnosis (years)	2.9 ± 4.2 (0–16)
Age at operation (years)	5.5 ± 4.2 (0–16)
Follow-up period (months)	29.1 ± 16.2 (6–63)
Bilaterality of Ahmed implant	
Bilateral	5 (17.2%)
Unilateral	24 (82.8%)
Diagnosis	
Congenital glaucoma	12 (35.3%)
Glaucoma following lensectomy for congenital cataracts	11 (32.4%)
Aphakic glaucoma	5 (14.7%)
Pseudophakic glaucoma	6 (17.6%)
Developmental glaucoma with associated ocular anomalies	5 (14.7%)
Aniridia	1 (2.9%)
Microphathalmia (complex)	1 (2.9%)
Axenfeld–Rieger anomaly	3 (8.8%)
Neovascular Glaucoma	4 (1.0%)
Developmental glaucoma with associated systemic disease[a]	1 (2.9%)
Glaucoma associated with cicatricial ROP[b]	1 (2.9%)

Abbreviation: ROP, retinopathy of prematurity.
[a]Down syndrome with unilateral congenital glaucoma.
[b]Cicatricial ROP with secondary angle closure.

The indications of the 19 patients (55.9%) that underwent primary AVI without any previous glaucoma surgery were: glaucoma following congenital cataract surgery (pseudophakic or aphakic glaucoma; $n=10$), neovascular glaucoma ($n=4$), severe anterior segment dysgenesis (Axenfeld–Rieger anomaly, complex microphthalmia $n=2$), congenital glaucoma with corneal opacity ($n=2$), and cicatricial retinopathy of prematurity (ROP) with corneal opacity ($n=1$).

Two eyes (5.8%) underwent combined procedures at the time of AVI. One was penetrating keratoplasty (PKP) in congenital glaucoma with total corneal opacity, and the other was anterior segment reconstruction consisting of lensectomy and pupilloplasty in complex microphthalmia.

Intraocular pressure was reduced from a preoperative mean of 37.5 ± 7.3 mm Hg (range, 22–58) to 18.4 ± 7.3 mm Hg (range, 3–34) ($P<0.01$) at 6 months, 22.9 ± 11.1 mm Hg (range, 11–35) at 12 months ($P<0.01$) and 21.8 ± 9.3 mm Hg (range, 19–39) at 24 months ($P<0.01$). The mean IOP at the last follow-up examination was 22.9 ± 11.1 mm Hg (range, 0–58), which was significantly lower than preoperative values.

The number of glaucoma medications significantly decreased from a preoperative mean of 2.3 (range, 1–4) to 1.4 (range, 1–3) at 6 months after AVI. The number of glaucoma medications was not significantly different from preoperative values at 12, 24 months, and the last follow-up examination (mean 1.8; range, 0–4; $P=0.17$, $P=0.86$, $P=0.41$ by Wilcoxon signed rank test).

After 12 months, 19 eyes (63.3%) met the criteria of qualified success, and 4 eyes (13.3%) showed complete success. Success rates declined over time, and at the last follow-up examination, 17 eyes (50.0%) showed qualified success and 6 eyes (17.6%) showed complete success (Table 2).

The cumulative probabilities of qualified success at 6, 12, and 24 months after AVI, according to life table analysis (Kaplan–Meier plot), were 89.0, 68.6, and 45.7%,

respectively. The median time of survival was 19.6 ± 0.9 months (Figure 1).

Univariate analysis of risk factors for failure, in terms of qualified success, was compared between subgroups. There was no significant difference in success rates at the last follow-up examination between subgroups of different diagnosis ($P = 0.06 \sim 0.83$), age ($P = 0.90$), presence of previous glaucoma surgery ($P = 0.79$; Table 3), or combined surgery ($P = 0.70$).

Postoperative complications occurred in six eyes (17.6%) after a mean interval of 6.3 ± 5.6 months (range, 0–17; Table 4). The most common complication was shallow anterior chamber, occurring in three eyes (8.8%). Hyphema occurred in two eyes (5.9%) with neovascular glaucoma, both of which spontaneously resolved. The most threatening complication developed in one eye (2.9%) of congenital glaucoma. Hypotony, shallowing of the anterior chamber, and choroidal detachment developed 3 months after AVI that was refractory to conservative management, followed by retinal detachment 9 months after surgery. Tube exposure was found in one eye (2.9%) 4 months after surgery and was surgically repaired with scleral graft and amniotic membrane transplantation. Tube occlusion by iris tissue segments developed in one eye (2.9%) together with shallow anterior chamber at 15 months after AVI. Surgical revision with anterior chamber reformation was successfully performed.

Of the five patients (17.2%) who underwent bilateral AVI, male to female ratio was 1 : 4, and the mean time interval between the operations of fellow eyes was 6.0 ± 12.0 months (range, 0–27). The preoperative mean IOP was not significantly different between fellow eyes ($P = 0.35$ by paired t-test). The mean follow-up time (35.4 ± 17.1 months; range, 12–63) was not different between fellow eyes ($P = 0.28$ by paired t-test). At 12 months after AVI, bilateral valve survival was found in two patients with congenital glaucoma and pseudophakic glaucoma (40%). Unilateral failure occurred in two patients (20%) with congenital glaucoma (3 months) and Axenfeld–Rieger anomaly (12 months). Bilateral failure occurred in one patient (20%) with aphakic glaucoma (1 month). No additional failure

Table 2 Success rates after Ahmed valve implantation

Period	*Number of eyes*	*Qualified success*[a]	*Complete success*[b]
Postoperative			
6 months	34	25 (73.5%)	8 (23.5%)
12 months	30	19 (63.3%)	4 (13.3%)
Last follow-up[c]	34	17 (50.0%)	6 (17.6%)

[a]Qualified success: IOP ⩽21 mm Hg regardless of the number of glaucoma medications.
[b]Complete success: IOP ⩽21 mm Hg without glaucoma medication.
[c]Last follow-up period was 29.1 ± 16.2 months (range, 6–63).

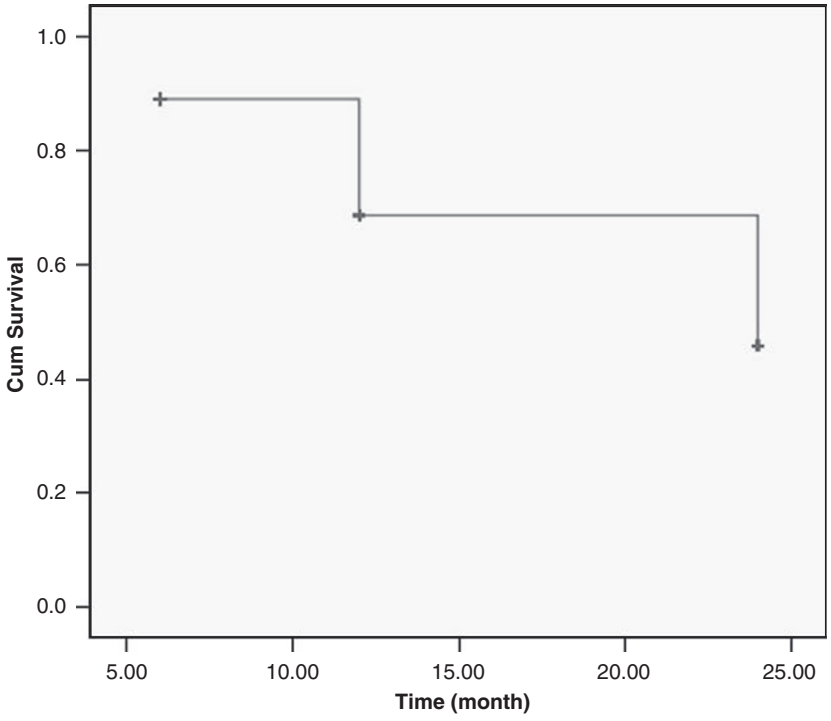

Figure 1 The cumulative probabilities of qualified success at 6, 12, and 24 months after Ahmed valve implantation, according to life table analysis (Kaplan–Meier plot), were 89.0, 68.6, and 45.7%, respectively. The median time of valve survival was 19.6 ± 0.9 months.

Table 3 Comparison of success rates at last follow-up after Ahmed valve implantation between subgroups of different diagnosis, age group, and previous glaucoma surgery

Glaucoma diagnosis	*Eyes (N)*	*Success*[a]	*Follow-up (mo)*
Congenital glaucoma	12	9 (75.0%)	40.6 ± 17.0
Aphakic/pseudophakic glaucoma	11	7 (63.6%)	20.0 ± 9.5
Glaucoma with ocular anomalies[b]	5	1 (20.0%)	25.2 ± 13.5
Neovascular glaucoma	4	1 (25.0%)	24.5 ± 13.9
Glaucoma with systemic disease[c]	1	0 (0%)	13.0 ± 0
Glaucoma associated with cicatricial ROP	1	1 (100%)	47.0 ± 0
P-value		0.06 ~ 0.83[d]	0.05[e]
Age at operation	*Younger group (0–5 years) % (N = 20)*	*Older group (6 ~ 18 years) % (N = 14)*	*P-value*
Success[a]	55.0% (11)	57.1% (8)	0.90[d]
Follow-up (mo)	30.0 ± 16.0	27.9 ± 17.0	0.67[f]
Previous glaucoma surgery	*Initial AVI % (N = 19)*	*Previous glaucoma surgery % (N = 15)*	*P-value*
Success[a]	57.9% (11)	53.3% (8)	0.79[d]
Follow-up (mo)	23.9 ± 13.0	35.7 ± 17.8	0.06[f]

Abbreviations: AVI, Ahmed valve implantation; mo, months; IOP, intraocular pressure; ROP, retinopathy or prematurity.
[a]Qualified success: IOP ⩽21 mm Hg regardless of the number of glaucoma medications.
[b]Glaucoma associated with aniridia, Axenfeld–Rieger anomaly, or microphthalmia.
[c]Glaucoma associated with Down syndrome.
[d]Univariate analysis of success rates between different subgroups by Pearson's χ^2-test.
[e]The follow-up period was not significantly different between subgroups by Kruskal–Wallis test.
[f]The follow-up period was not significantly different between subgroups by Mann-Whitney *U* test.

Table 4 Postoperative complications after Ahmed valve implantation

Complication	*Number of eyes N (%)*	*Postoperative Period (months)*	*Treatment*
Shallow anterior chamber[a]	3 (8.8%)	0, 0, 15	Chamber reformation
Hypotony (IOP < 5 mm Hg)	1 (2.9%)	3	Observation[b]
Hyphema	2 (5.9%)	0, 0	Spontaneous resolution
Tube exposure	1 (2.9%)	4	Scleral graft
Tube occlusion	1 (2.9%)	15	Surgical revision[c]
Choroidal detachment	1 (2.9%)	3	Observation[b]
Retinal detachment	1 (2.9%)	9	Observation[b]
No complications	28 (82.4%)		

[a]Shallow anterior chamber was the most common complication, occurring in three eyes (8.8%) due to congenital glaucoma, complex microphthalmia, and neovascular glaucoma in insulin dependent diabetes mellitus.
[b]Hypotony, choroidal detachment, and retinal detachment all developed in one eye during follow-up. The patient had band keratopathy and near total corneal opacity prior to Ahmed valve implantation. No further intervention was performed as the parents declined additional procedures.
[c]Tube occlusion was partial by iris tissue segments plugging the tube orifice, following a flat anterior chamber. The occlusive tissues were surgically removed at the time of anterior chamber reformation.

occurred after 12 months and no significant complications were found in all eyes until the last follow-up examination.

Of the 11 eyes (32.4%) that failed after AVI, 5 eyes (45.5%) underwent second AVI in the superonasal quadrant. The mean number of previous glaucoma surgeries before Ahmed implant was 3 (range, 1–5). The time interval between the successive implantations was 18.8 ± 7.9 months (range, 13–32). The mean follow-up time after the second AVI was 26.6 ± 12.7 months (range, 12–47). Four eyes (80%) showed qualified ($n = 2$; 40%) or complete ($n = 2$; 40%) success at the last follow-up examination without any significant complications.

Discussion

Success rates after AVI in refractory paediatric glaucoma are variable in previous reports, but all show a relative decline over time.[9,36–38] The cumulative probabilities of success rates reported at 1, 2, 3, and 4 years after AVI is

70–93, 50–86, 52–71, and 42–45%, respectively.[29,30,33,39,40] Other implants, such as Molteno or Baerveldt implants, have shown similar success rates and valve survival.[23–25,37] In this study, the cumulative probability of qualified success at 6, 12, and 24 months after AVI in patients younger than 18-year-old were 89.0, 68.6, 45.7%, respectively. This falls to the lower end of success rates demonstrating limited success.[29,30,33,39,40]

The different type of valve used may be one reason of limited success. In this study, Ahmed valves designed for children (S-3) were used for patients under 12 years, instead of the adult model (S-2). Although the tube properties are equal, the S-3 model is slightly smaller in valve width and length and the surface area is half the size of the adult model. A smaller model may be preferred in paediatric patients to prevent tube-corneal contact, which tends to occur in eyes of very young patients with low scleral rigidity, perhaps because of anterior rotation of the tube due to lower holding power of sclera around the tube and postoperative depression of sclera by the volume of the plate.[41] However, the reduced surface area and width of the valve may be related to decreased filtration, resulting in limited success as in this study. Hence, an ultrasonic biometry of globe size may be useful in deciding the size of the implant. However, in our study, qualified success rates of the S-3 model were not different with the S-2 model ($P = 0.59$ by Fisher's exact test) and was not related to patients age ($P = 0.80$ by Mann–Whitney U test). As globe size or corneal diameter was not included in this study, it remains to be elucidated whether the paediatric model (S-3) is more useful in patients with a smaller globe. This promotes the use of ultrasonic biometry to select candidates for the S-3 model.

The lack of postoperative manipulations may be another reason of limited success. In our study, postoperative needling was barely possible due to general conditions and poor cooperation of young patients. This may be why postoperative needling, although effective in adults, is seldom described in studies of refractory paediatric glaucoma.[32,42–44]

Risk factors for failure after AVI were not evident in our study. Qualified success rates of AVI at last follow-up were not significantly different between subgroups of specific glaucoma diagnosis, age at the time of surgery, presence of previous glaucoma surgery, or combined surgical procedures. However, studies are controversial concerning risk factors for failure after AVI. One of the most common risk factors is glaucoma diagnosis. Djodeyre *et al*[39] noted that congenital glaucoma, number of previous glaucoma surgeries, and surgical experience were significantly related to valve survival. Coleman *et al*[29] also suggested a higher risk of failure in eyes with congenital glaucoma than in eyes with other diagnoses in the paediatric population. Nevertheless, others have reported high success rates (92.9%) in congenital glaucoma patients.[40] Our study also demonstrated a high success rate (75.0%) in congenital glaucoma patients after a mean follow up of 40.6 ± 17.0 months, which was not significantly different between other diagnoses.

One eye underwent combined PKP with AVI, and qualified success was maintained up to 4 years after surgery. Coleman *et al*[45] presented figures of cumulative probability of success as 76% at 12 months and 52% at 20 months in eyes having AVI with prior or concurrent PKP in adult glaucomas. This was comparable to success rates after simple glaucoma valve surgeries, which suggests that combined PKP does not influence the survival of AVI in children and adults.

The advantage of AVI over filtration surgery or other non-valved implants can be explained as follows. The Ahmed valve consists of a flexible drainage tube and an equatorial plate, which are made up of materials (polymethylmethacrylate, polypropylene, silicone rubber) relatively resistant to fibroblast attachment. The internal diameter of the tube does not narrow, letting floating matter in the anterior chamber pass through the tube without occlusion. The unidirectional valve that opens at pressures over 8 mm Hg can prevent immediate postoperative hypotony or IOP spikes.[46] The equatorial filtration blebs are also beneficial in maintaining the initial bleb size and function, through their lower propensity toward contraction of the fibrous capsule compared to the limbal blebs of trabeculectomy.[24,47] Antimetabolites such as mitomycin C or 5-fluorouracil can be applied to prevent excessive scar formation; however, some authors report a higher risk of complications in the paediatric population compared to adults.[48–50]

Postoperative complications after AVI include hypotony (IOP $\leqslant$ 5 mm Hg) (11–42%), shallow anterior chamber (15 ~26%), tube malposition (5~26%), tube-corneal touch (3~8%), tube occlusion (14%), tube exposure (6~12%), and other rare complications such as tenon encapsulated cyst (1~7%), postoperative cataract (0~2%), strabismus (0~3%), retinal or choroidal detachment (1~18%), endophthalmitis (1~5%), wound leak (3%), plate migration (2%), inflammation, hyphema, delayed retrobulbar haemorrhage.[28–30,33,39,51,52] In our study, overall rates of complications was lower than previously reported. Shallow anterior chamber (8.8%) was most commonly encountered, but found in a lower rate compared to other studies. Most of the complications occurred within 4 months, whereas one eye developed partial tube occlusion with iris tissue plugging due to flattening of the anterior chamber at 15 months after AVI. Trigler *et al*[53] histologically documented one of the causes of tube occlusion as the presence of fibrovascular

ingrowth in their Ahmed glaucoma valve, and the mean time to failure and explantation was 23 months after implantation (range, 6–65 months). However, in our case, tube occlusion with iris tissues plugging the orifice was surgically managed without causing valve failure.

One devastating complication occurred in a patient with congenital glaucoma. Hypotony, flat anterior chamber, and choroidal detachment developed 3 months after surgery, followed by retinal detachment. In this case, band keratopathy was present prior to AVI, and AVI had been performed for pain and IOP control. Further intervention was not possible as the parents declined additional procedures. Retinal detachment is rarely reported after AVI, but the rates in our study (2.9%) were similar to those reported with other implants.[23,26,54] Retinal detachment following choroidal detachment is reported after severe ocular inflammation,[55] but in our case, there was no sign of severe inflammation. A silent retinal tear or shallow retinal detachment may have been present much earlier in the development of hypotony, masked by choroidal detachment.[56,57]

Treatment is required after certain complications. Two eyes that failed shortly after surgery showed corneal decompensation requiring PKP. Iris tissues causing tube occlusion along with flat anterior chamber were surgically removed at the time of anterior chamber reformation. Tube exposure was managed with scleral patch graft and amniotic membrane graft. Hypotony and choroidal detachment was observed without management due to near total corneal opacity and poor compliance. Most cases of postoperative choroidal detachment resolve spontaneously, usually associated with rapid normalization of IOP and reduction of inflammation.[56] Surgical management involving vortex vein decompression or sclerotomy can be effective in some patients.[58] In our case, hypotony was sustained, progressing unto retinal detachment, suggesting the possibility of a preexisting retinal detachment not found until later progression. No further interventions were taken according to the parents' will. Other non-devastating complications spontaneously resolved or were asymptomatic (Table 4).

The presence of a hypertensive phase, defined as IOP >21 mm Hg during the first 3 months after surgery, was seen in 20 eyes (59%). This is comparable to previous studies, which showed a hypertensive phase in 25$\sim$82% of patients after AVI in adults.[30,59] The incidence of a hypertensive phase is known to be more frequent after AVI compared to non-valve implantation.[59] Nouri-Mahdavi and Caprioli[59] found a hypertensive phase in 56% of adults after AVI, but resolution of the hypertensive phase was observed in only 28%. However, in paediatric glaucoma, Chen *et al*[30] found 25$\sim$40.4% having a hypertensive phase, demonstrating a lower incidence in children compared to adults.

The resolution of the hypertensive phase, defined as an IOP $\leqslant$21 mm Hg and IOP reduction of 3 mm Hg with the same or fewer number of glaucoma medications, was found in 15 out of 20 eyes (75%). The resolution rate was much higher than in adults (28%), suggesting better control of transient IOP elevation after AVI in children.[59]

Additional AVI after failure of the primary implant was found to be effective in our study. Out of 11 failed eyes, 5 (45.5%) underwent additional AVI without removal of the primary implant. This was carried out under the notion that removal of the primary implant was traumatic, and the failed valve may still be partially functioning. Four eyes (80%) survived at last follow-up (mean, 26.6 $\pm$ 12.7 months), whereas long-term valve survival remains to be elucidated.

Despite the limitations of its retrospective nature and small number of cases in this study, AVI seems to be effective in refractory paediatric glaucoma. The paediatric model (S-3) showed comparable but limited success rates. Selective candidates for a smaller valve remain to be elucidated. Success rates decline over time, and considering the need for longer valve survival in the paediatric population, efforts to develop alternative medications or surgical procedures are promoted for long-term survival. Additional AVI may be considered as a treatment option after failure of the primary implantation.

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