Ahmed Glaucoma Valve Implantation with the Tube Placement in the Ciliary Sulcus: Short Term Results

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Research Article

Keywords: Ahmed glaucoma valve, ciliary sulcus, glaucoma drainage implant, tube shunt surgery

Posted Date: March 4th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-264845/v1

Version of Record: A version of this preprint was published at International Ophthalmology on October 10th, 2021. See the published version at https://doi.org/10.1007/s10792-021-02080-w.

Abstract

Purpose: To evaluate the clinical outcomes of pseudophakic/aphakic eyes with uncontrolled glaucoma that underwent Ahmed glaucoma valve implantation with the tube placement in the ciliary sulcus.

Methods: Medical records of the patients who underwent Ahmed glaucoma valve implantation through the ciliary sulcus, between December 2017 and June 2019, were reviewed retrospectively. Patients' age, gender, glaucoma diagnosis, visual acuity, intraocular pressure levels and complications were recorded.

Results: Forty-seven eyes of 43 patients with glaucoma were enrolled. The mean age was 54.5 ± 19.9 years (range, 7 - 88 years) at the time of surgery and the mean postoperative follow-up period was 7.9 ± 3.4 months (range, 3 -16 months). The mean preoperative intraocular pressure level was 35.2 ±6.8 mmHg (range, 25-55 mmHg) and it was found as 15.6 ± 5.4 mmHg (range, 9-33 mmHg) at last follow-up visit. Decrease in intraocular pressure level was statistically significant ($P < 0.001$). At last follow-up visit success was achieved in 41 eyes (87.2 %). Hyphema was the most common postoperative complication and developed in 11 eyes (23.4%) and resolved spontaneously in all of them within one month.

Conclusion: In pseudophakic or aphakic eyes with uncontrolled glaucoma, placement of Ahmed glaucoma valve tube in the ciliary sulcus is a safe and effective procedure. Ciliary sulcus can be considered as a potential space during tube shunt surgery in eyes with high risk of tube-corneal touch or corneal decompensation.

Introduction

Glaucoma drainage devices have been used widely for many years in the management of refractory or complicated glaucoma cases and usually preferred when trabeculectomy has failed or is unlikely to succeed. In recent years there is a rise in frequency and indication of glaucoma drainage device (GDD) implantation [1, 2].

During GDD surgery, typically, silicone tubes are inserted into the anterior chamber (AC) through the AC angle. However, it is well known that tube in the anterior chamber may lead to corneal endothelial cell loss and eventually corneal decompensation. The risk is particularly higher in eyes with shallow AC depth or compromised corneal endothelium and those with corneal transplants [3–6]. In order to avoid these serious corneal complications, pars plana insertion of the GDD tube has been described [7–10]. In this situation, complete pars plana vitrectomy should have been done either prior to or concurrent with the tube placement. Ciliary sulcus is another potential space for the tube placement. Ciliary sulcus insertion of the GDD tube is not a new procedure and was first described by Rumelt and Rehany in 1998 [11]. We think this surgical modality has not gained much attention or interest among the ophthalmologists. Only few studies and case reports have been published in the literature about this surgical approach and most of them relate outcomes of Baerveldt implant [11–18]. Ahmed glaucoma valve (AGV; New World Medical Inc., Rancho Cucamonga, CA, USA) is mostly used and readily available GDD in our country and recently, we also have begun to insert the AGV tube into the ciliary sulcus in certain glaucoma cases. We prefer

this surgical technique in aphakic/ pseudophakic eyes in which there is high risk of corneal decompensation after AC tube shunt placement such as the presence of shallow AC depth, compromised corneal endothelium or corneal transplant. Since our hospital is a tertiary referral center in the region, we often encounter refractory or complicated glaucoma cases such as primary or secondary angle closure glaucoma, glaucoma associated with vitreoretinal surgery, aphakic glaucoma, traumatic, uveitic or postkeratoplasty glaucoma. Herein, we report our short-term results of glaucoma patients who underwent AGV implantation with the tube placement in the ciliary sulcus. The current study presents the results of 47 eyes of 43 patients from a single center.

Methods

We reviewed the medical records of consecutive patients who underwent Ahmed glaucoma valve (model FP7, New World Medical Inc., Rancho Cucamonga, CA, USA) implantation with the tube placement in the ciliary sulcus in our clinic between December 2017 and June 2019, retrospectively.
The study protocol was approved by the ethics committee of Dokuz Eylul University (2019/25–43) and conducted in accordance with the ethical principles described by the Declaration of Helsinki.
Implantation of AGV was performed in eyes with increased IOP that was not responsive to medical therapy. We preferred to implant the AGV tube into the ciliary sulcus in aphakic or pseudophakic eyes in the presence of one of the following situations: Shallow AC depth, extensive peripheral anterior synechiae, compromised corneal endothelium, presence of corneal graft or being candidate for keratoplasty. Patients' age, sex, glaucoma diagnosis, previous glaucoma surgeries, aphakia/pseudophakia status, best corrected visual acuity (BCVA) levels, intraocular pressure (IOP) levels, number of antiglaucoma medications (a fixed combination drug was counted as 2 drugs), intraoperative and postoperative complications were recorded. Intraocular pressure was measured with Goldmann applanation tonometer in all patients. Deterioration of BCVA was defined as 1) Loss of ≥ 2 Snellen lines; 2) Deterioration by one or more step between counting fingers (CF), hand motion (HM), light perception (LP) or 3) Loss of LP. Eyes with follow-up shorter than 3 months were excluded.

Surgical Technique

All surgeries were performed under local (sub-Tenon) or general anesthesia by the same glaucoma surgeon (G.A.) Supero-temporal quadrant was the preferred site for the tube shunt placement. However, if this quadrant was not suitable, the other quadrants were also used for GDD implantation. A clear corneal traction suture was placed to obtain appropriate surgical exposure. A fornix-based conjunctival flap was made. Before implantation, tube was irrigated with balanced salt solution to ensure its patency. The plate is secured to the globe with 6 – 0 vicryl suture with the anterior edge 8–10 mm posterior to the limbus. To prevent postoperative hypotony, partial ligation of the tube was done externally with 8 – 0 vicryl suture near the plate. To expand the ciliary sulcus space, viscoelastic agent was injected into the ciliary sulcus behind the iris where the tube was planned to insert. A sclerostomy was made approximately 2 mm posterior to the limbus with a 22-gauge needle. The needle was advanced posterior and paralel to the iris plane until the tip of the needle was noted in the pupillary area. The tube was cut to an appropriate length

with a beveled-up fashion so that the tip of the tube was just visible at the pupillary margin (Fig. 1, Fig. 2). Then the tube was inserted into the ciliary sulcus through the needle track. The tube was fixated to the sclera with 10 – 0 nylon suture and then covered with pericardium patch graft. Conjunctiva was closed with 8 – 0 polyglactin suture. Topical steroids and antibiotics were given six times daily in the postoperative period. Antibiotics discontinued after one week and topical steroids tapered over 6 weeks. Postoperatively, all glaucoma medications were stopped and were started in the follow-up period based on IOP level.

Follow-up visits were scheduled 1 day, 1 week, 1 month, 2 months, 3 months and every 3 months thereafter. Surgical success was defined as postoperative IOP ≥ 6 mmHg and ≤ 21 mmHg with or without antiglaucomatous medications. Failure was defined as inadequate IOP control on two consecutive study visits, necessity of further glaucoma surgical intervention (cyclophotocoagulation or filtration surgery), loss of light perception or removal of the GDD. Hypotony (IOP < 6 mmHg) was also considered as failure.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, version 24 (IBM Corp., Armonk, N.Y., USA). Quantitative data were expressed as mean ± standard deviation and categorical variables as percentage. Paired samples T test and Wilcoxon signed rank test were used for comparing differences between continuous variables. Snellen BCVA measurements were converted to the logarithm of the minimum angle of resolution (logMAR) visual acuity equivalents for the statistical analysis. The cumulative probability of success was derived using Kaplan-Meier life-table analysis. Analyses were considered to be statistically significant when the *P* value was < 0.05.

Results

Baseline Characteristics

A total of 47 eyes of 43 patients were included in the study. Mean age was 54.5 ± 19.9 years (range, 7–88 years) at the time of AGV surgery. The study population consisted of 25 male (58.1%) and 18 female (41.9%) patients. The mean postoperative follow-up period was 7.9 ± 3.4 months (range, 3–16 months). Fifteen eyes (31.9 %) had undergone previous glaucoma intervention (laser cyclophotocoagulation or glaucoma surgery), whereas remaining 32 eyes (68.1%) underwent primary AGV implantation surgery. Table 1 shows the baseline clinical characteristics of the eyes. Most of the eyes were pseudophakic and the most frequent diagnosis was neovascular glaucoma. One patient who was diagnosed with neovascular glaucoma and visually significant cataract, underwent combined cataract surgery (phacoemulsification and intraocular lens implantation) and AGV implantation. One patient who had glaucoma associated with vitreoretinal surgery and corneal opacity underwent penetrating keratoplasty and AGV implantation surgery simultaneously. Thirteen eyes (27.7 %) had history of previous corneal transplantation.

Table 1
Clinical characteristics at baseline

Characteristics	
Age (years), mean ± SD	54.5 ± 19.9
Sex [no.(%)]	
Female	18 (41.9)
Male	25 (58.1)
Study eye [no.(%)]	
Right	28 (59.6)
Left	19 (40.4)
Lens status [no.(%)]	
Phakic*	1 (2.1)
Pseudophakic	40 (85.1)
Aphakic	6 (12.8)
Glaucoma diagnosis [no.(%)]	
Neovascular glaucoma	15 (31.9)
Primary angle closure glaucoma	6 (12.8)
Secondary angle closure glaucoma (microspherophakia)	2 (4.3)
Postkeratoplasty glaucoma	7 (14.9)
Glaucoma associated with vitreoretinal surgery	4 (8.5)
Posttraumatic glaucoma	1 (2.1)
Aphakic glaucoma	6 (12.8)
Pseudophakic glaucoma	2 (4.3)
Primary open angle glaucoma	3 (6.4)
Congenital glaucoma	1 (2.1)
Previous glaucoma procedures [no.(%)]	

AGV:Ahmed glaucoma valve, ECP: endoscopic cyclophotocoagulation, IOP: intraocular pressure, IOL: intraocular lens, LogMAR: logarithm of the minimum angle of resolution, PE: phacoemulsification, SD: standard deviation, TSDLC: transscleral diode laser cyclophotocoagulation

*Combined surgery (PE + IOL + AGV implantation) was performed.

Characteristics	
Only trabeculectomy	8 (17.0)
Only TSDLC	3 (6.4)
First trabeculotomy, later trabeculectomy	1 (2.1)
Phacotrabeculectomy	1 (2.1)
First AGV implantation, later ECP	1(2.1)
First trabeculectomy, later TSDLC	1(2.1)
Total number of eyes underwent glaucoma procedure previously	15 (31.9)
Previous keratoplasty [no.(%)]	13 (27.7)
Preoperative IOP (mmHg), mean ± SD	35.2 ± 6.8
Preoperative number of glaucoma medications, mean ± SD	3.6 ± 0.5
Preoperative visual acuity (logMAR), mean ± SD	1.8 ± 0.9
AGV:Ahmed glaucoma valve, ECP: endoscopic cyclophotocoagulation, IOP: intraocular pressure, IOL: intraocular lens, LogMAR: logarithm of the minimum angle of resolution, PE: phacoemulsification, SD: standard deviation, TSDLC: transscleral diode laser cyclophotocoagulation	
*Combined surgery (PE + IOL + AGV implantation) was performed.	

Intraocular Pressure Outcomes

The mean preoperative IOP was 35.2 ± 6.8 mmHg (range, 25–55 mmHg) and it was reduced to 15.6 ± 5.4 mmHg (range, 9–33 mmHg) at last follow-up visit. Decrease in IOP level was statistically significant (P< 0.001, paired samples T test). The mean IOP levels at baseline and at each follow-up visit are shown in Fig. 3 and Table 2. In all time points after the AGV implantation, mean IOP level was statistically significantly lower when compared with the mean baseline IOP level (Table 2). At last follow-up visit, success was achieved in 41 eyes (87.2 %). Failure was due to high IOP level in 4 eyes, loss of light perception in one eye and removal of the implant in one eye. Kaplan – Meier survival curve after AGV implantation is shown in Fig. 4. The cumulative probability of success was found as 94.9 % at 6 months and 70.9 % at 12 months. The mean preoperative number of glaucoma medications was reduced from 3.6 ± 0.5 (range: 3–4) to 1.6 ± 1.6 (range: 0–4) at last follow-up visit (P< 0.001, paired samples T test). Twenty-one eyes (44.7 %) required no IOP lowering medication at final visit.

Table 2
Mean intraocular pressure (mmHg) at baseline and at each follow-up visit

Time	No.	IOP mean ± SD	IOP range	*P* value
Baseline	47	35.2 ± 6.8	25–55	
Day 1	47	8.0 ± 2.7	2–17	< 0.001 [a]
Week 1	47	10.2 ± 2.9	2–18	< 0.001 [a]
Month 1	47	13.9 ± 4.4	7–30	< 0.001 [a]
Month 2	47	15.0 ± 4.3	8–28	< 0.001 [a]
Month 3	47	15.6 ± 3.2	10–30	< 0.001 [a]
Month 6	39	16.1 ± 4.1	10–28	< 0.001 [a]
Month 9	23	14.9 ± 4.9	9–33	< 0.001 [b]
Month 12	11	16.6 ± 7.2	10–32	0.03 [b]
Final visit	47	15.6 ± 5.4	9–33	< 0.001 [a]

IOP: intraocular pressure, SD: standard deviation

[a]Paired samples T test

[b]Wilcoxon signed rank test

Visual Acuity Outcomes

The mean BCVA was 1.8 ± 0.9 logMAR (range, 0–3) preoperatively and it was found as 1.5 ± 0.9 logMAR (range, 0–3) at last follow-up visit. There was significant difference between preoperative and postoperative mean logMAR visual acuity data ($P = 0.002$, paired samples T test) and postoperative BCVA was found to be better when compared to preoperative BCVA. Final BCVA remained the same in 26 eyes (55.3 %), improved in 10 eyes (21.3%) and deteriorated in one eye (2.1%) when compared to preoperative visual acuity levels. Improvement in visual acuity was mostly due to resolution of the corneal edema. In 2 eyes underwent combined surgery with AGV implantation, keratoplasty in one eye and cataract extraction in the other eye made contribution to increase in visual acuity. At last follow-up visit, loss of light perception was developed in a diabetic patient diagnosed with neovascular glaucoma who also had total glaucomatous optic atrophy and visual acuity of hand motion at baseline. During the early postoperative period, increase in IOP was recorded and visual acuity decreased to LP. At 3 months after surgery, he diagnosed with bacterial keratitis and S. pneumoniae was isolated from his corneal scrapings. Although

IOP remained in normal level thereafter, loss of LP was recorded at his last follow-up visit. Except for this patient, deterioration of visual acuity did not occur in any eye.

Complications

No complications were observed during the surgery. Postoperative complications and further operations performed for their management are shown in Table 3. Some eyes had more than one type of complication. Overall 30 eyes (63.8 %) had one or more complication after the surgery. Hyphema was the most common postoperative complication and developed in 11 eyes (23.4%) and mostly occurred in eyes with neovascular glaucoma (9 eyes had neovascular glaucoma, one eye had angle closure glaucoma and one eye had glaucoma associated with vitreoretinal surgery). All hyphemas resolved spontaneously within the postoperative first month. Shallow/ flat AC was observed in 5 eyes (10.6%) in the early postoperative period. It was associated with hypotony in 3 eyes and it was due to malignant glaucoma in 2 eyes. Eyes with hypotony and shallow /flat AC were managed conservatively without the need to any surgical intervention. Malignant glaucoma developed in 2 pseudophakic eyes (4.3%) with primary angle closure glaucoma. In one eye malignant glaucoma resolved with the use of cycloplegia, aqueous suppressants and hyperosmotic agents. The other eye did not respond to medical management and underwent pars plana vitrectomy with iridozonulohyaloidectomy. Choroidal effusion developed in 2 eyes (4.3%) and resolved spontaneously. Tube occlusion occurred in 2 eyes (4.3%) diagnosed with aphakic glaucoma and it was due to vitreous incarceration in the tube opening. In one eye, it was developed at 2 weeks and in the other eye, it was developed at 6 months after the AGV implantation. Anterior vitrectomy was performed in these 2 eyes for resolving the tube obstruction. Bleb encapsulation was developed in 8 eyes (17%) in which IOP remained high despite antiglaucomatous medication. Excisional bleb revision was performed in 7 of them. Plate exposure developed in one patient (a 15-year-old boy diagnosed with aphakic glaucoma) after excisional bleb revision procedure. Despite conjunctival autografting was performed to close the defect, plate exposure was persisted and extended in this case. Finally, implant was explanted and transscleral diode laser cyclophotocoagulation was applied later. Tube exposure also developed in one eye diagnosed with neovascular glaucoma; in which erosion of the conjunctiva over the tube occurred at 3 months after AGV implantation and it was surgically repaired with using Tenon’s cyst autograft.

Table 3
Postoperative complications and further operations

Complications	**No. (%)**
Hyphema	11 (23.4)
Transient hypotony (< 1 month)	7 (14.9)
Shallow/flat anterior chamber	3 (6.4)
Choroidal effusion	2 (4.3)
Tube exposure	1 (2.1)
Plate exposure	1 (2.1)
Blockage of the tube tip by vitreous	2 (4.3)
Bleb encapsulation	8 (17.0)
Malignant glaucoma	2 (4.3)
Infectious keratitis	2 (4.3)
Commencement of the tube tip by iris	3 (6.4)
Total number of eyes with complications	30 (63.8)
Further operation	
Excisional bleb revision for bleb encapsulation	7 (14.9)
Transscleral diode laser cyclophotocoagulation	5 (10.6)
Anterior vitrectomy to resolve tube obstruction	2 (4.3)
PPV + iridozonulohyaloidectomy	1 (2.1)
Autograft for tube exposure	1 (2.1)
Autograft for plate exposure	1 (2.1)
AGV implant removal	1 (2.1)
Total number of eyes required further operation	12 (25.5)
AGV: Ahmed glaucoma valve, PPV: pars plana vitrectomy	

Persistent uveitis or pigment dispersion were not seen in any eye. Implant dislocation or postoperative constant tube-corneal touch were not seen also. However, in the follow-up period, we noticed that in 3 eyes the tube tip was not visible in the pupillary area and commenced by the iris. But when the pupils were dilated, the tubes were visible near the pupillary border. In these 3 eyes, IOP was within normal limits during the follow-up period and the iris did not block the tube as well. In all the other eyes, the tube tips were visible near the pupillary margin during follow-up period and none of the patients were aware of the

presence of the tube tip near their visual axis. Vision-threatening complications such as endophthalmitis, suprachoroidal hemorrhage, retinal detachment, cystoid macular edema, phthisis bulbi, persistent ocular hypotony or hypotony maculopathy did not occur. In the follow-up period, denovo corneal edema/decompensation or corneal graft edema/decompensation did not develope in any eye that had clear cornea or corneal graft preoperatively.

Discussion

Corneal endothelial failure is a well-known complication after AC tube shunt placement [2, 3]. To minimize the corneal endothelial cell loss after GDD implantation, ciliary sulcus can be considered as a potential space for the tube shunt placement, especially in eyes with shallow AC depth or compromised corneal endothelium. Ciliary sulcus tube shunt implantation was first described by Rumelt and Rehany and they performed this procedure in 3 glaucoma patients who had previous corneal transplant surgery [11]. In these 3 patients ciliary sulcus insertion of the tube was performed by the authors owing to the combination of pseudophakia or aphakia, corneal graft and moderate shallowing of the AC. They used AGV in two eyes and Molteno implant in one eye. During the mean follow-up of 18 months, IOP readings were found to be in normal level (range, 8–14 mmHg) without any antiglaucomatous medication and corneal grafts remained unchanged. Authors suggested this surgical approach in pseudophakic or aphakic eyes with primary corneal diseases (i.e., Fuchs endothelial dystrophy), corneal transplants, shallow anterior chamber or extensive synechial angle closure. After their publication, this surgical technique has been supported by various studies and case reports in the literature [11–18]. In the present study, we investigated the clinical outcomes of AGV tube implantation into the ciliary sulcus in our patients and our short-term results showed that ciliary sulcus implantation of the tube shunt was a safe and effective procedure. Our overall success rate at final visit was found as 87.2 % and that was comparable with the previous studies related to ciliary sulcus tube shunt implantation in which success rates were reported between 78.6% and 100 % [12–14, 17, 18]. However, direct comparison of the results of different studies is imprecise due to the differences in the distribution of glaucoma diagnosis, follow-up periods, definition of success criteria and implanted GDD type. In one of these studies, Eslami et al. [14] reported the outcomes of the AGV tube implantation into the ciliary sulcus in aphakic and pseudophakic eyes. They evaluated 23 eyes of 23 patients retrospectively with the mean follow-up period of 9 months (range, 3–24 months). In their study, IOP reduced from 37.9 ± 12.4 mmHg to 16.2 ± 3.6 mmHg at last follow-up visit and they achieved a success rate of 78.6%. Reported serious complications were endophthalmitis (one eye), tube exposure (one eye) and vitreous tube occlusion (one eye). Authors concluded that placement of the tube in the ciliary sulcus was a safe and effective procedure. Bayer et al. [18] conducted a retrospective study comparing the efficacy and safety of AC angle (68 eyes) vs ciliary sulcus (35 eyes) placement of AGV tube. They reported no difference in success rates (success rate was 85.3 % in the ciliary sulcus group with a mean follow-up period of 30.2 ± 17.7 months and 83.8% in the AC angle group with a mean follow-up period of 27.2 ± 16.5 months). Although they found the mean IOP and the number of glaucoma medications at final visit similar in both groups, IOP reduction ratio was found to be higher in the ciliary sulcus insertion group. They could not provide an explanation for this

difference between the groups, but they proposed that, decrease in secretion of aqueous in the ciliary sulcus insertion group due to mechanical or toxic effects of the silicone tube on the ciliary body might have been the cause.

Like previous reports, hyphema was found to be the most frequent (24.3%) postoperative complication in our study. Hyphema was mostly encountered in eyes diagnosed with neovascular glaucoma and all hyphemas resolved spontaneously within one month. In Bayer et al's study the incidence of hyphema was found as 17.6% in the AC group and 14.3% in the ciliary sulcus group and they reported no differences between the groups [18]. Weiner et al. [13] implanted Baerveldt-350 tube shunt into the ciliary sulcus in 36 pseudophakic eyes and they found a high rate of hyphema (27.8 %) compared to TVT study (%2) in which Baerveldt-350 tube shunt was implanted into the AC. Authors attributed this high rate of hyphema due to the more vascularized tissues of the ciliary sulcus compared with the angle or pars plana.

Progressive corneal endothelial cell loss and eventual corneal decompensation is a well-known complication of AC tube shunt procedures [3–5, 19, 20]. The rate of corneal complications after AGV implantation was reported as high as 16–27% in previous reports and the risk was found to be higher in eyes with corneal graft [6, 20–23]. The exact mechanism of corneal endothelial cell loss after the tube shunt surgery has not been fully understood, but intermittent tube-corneal contact (by eye rubbing, squeezing, and even blinking), tube-uveal touch, turbulence present at the tip of the tube, chronic inflammation and foreign body reaction to the silicone tube itself are the proposed mechanisms [3, 4, 24]. Postoperative complications such as flat AC or constant tube-corneal touch may also cause corneal endothelial cell damage. Placing the tube in the AC, especially in eyes with shallow anterior segments, promotes tube – corneal touch, but ciliary sulcus placement of the tube makes this possibility quite remote. So, in eyes with shallow AC, we preferred to insert the silicone tube into the ciliary sulcus instead of the AC angle. We did not observe constant tube-corneal touch in any eye during the follow-up period. A final visit, corneal decompensation was not seen in any eye with preoperative clear cornea, but it should be noted that our follow-up period was short. Studies evaluating the corneal endothelium in eyes with AC tube shunts have shown that there is a constant insult to the corneal endothelium near the silicone tube and it has been suggested to place the tube as far from the cornea as possible to protect the corneal endothelium [4, 24]. In another study, endothelial contact at the insertion point of the tube was proposed as a risk factor for corneal endothelial cell loss in AC tube shunt surgery and authors recommended entry site of the tube to be posterior to Schwalbe's line to avoid corneal endothelial trauma [25]. In this regard, ciliary sulcus implantation of the tube shunt seems to be more confident for the corneal endothelium than AC angle. Currently, in aphakic/pseudophakic eyes with corneal graft or compromised corneal endothelium, ciliary sulcus is our priority choice for the tube placement to protect the corneal endothelium. Weiner et al. [13] implanted Baerveldt glaucoma implant in the ciliary sulcus of the 36 eyes in which there was high risk of corneal decompensation like shallow anterior chamber, corneal graft, corneal guttata, or corneal edema. During the mean follow-up period of 21.8 ± 16.6 months, corneal decompensation was observed in only one eye with preoperative clear cornea. So that the authors stated that the tube insertion through the ciliary sulcus during GDD surgery was a safe and effective procedure.

In another study with a mean follow-up period of 37.2 ± 18.9 months, Prata et al. [17] reported no case of postoperative corneal decompensation or graft failure in 17 eyes underwent ciliary sulcus Baerveldt glaucoma implant. Ciliary sulcus is also our priority choice for the tube placement in aphakic/pseudophakic eyes with extensive peripheral anterior synechiae like neovascular glaucoma. In eyes with extensive peripheral anterior synechia, sometimes it is very difficult or even inapplicable to insert the tube properly through the iridocorneal angle into the AC. Moreover, in a previous report, presence of the peripheral anterior synechiae was proposed as a risk factor for the corneal endothelial cell loss [26]. Although ciliary sulcus tube shunt placement seems to be safe for corneal endothelium, to our knowledge, no study has examined corneal endothelial cell change after ciliary sulcus tube shunt placement to date. Future studies with specular microscopy evaluating progression of corneal endothelial cell changes in eyes that underwent ciliary sulcus tube shunt placement will be more informative in this regard.

In the past, pars plana tube insertion with complete pars plana vitrectomy had been advocated in eyes where AC tube insertion could not be possible or ideal [7–10]. Although it has been shown as an effective procedure, pars plana insertion may lead to significant posterior segment complications such as retinal break, retinal detachment, vitreous hemorrhage, epiretinal membrane formation and even blindness. Furthermore, tube blockage also reported after pars plana implantation due to residual vitreous [10]. Along with posterior segment complications, pars plana approach adds additional cost and extends the operation time also. Ciliary sulcus insertion is more simpler, time saving and less invasive procedure compared to pars plana insertion. Thus, we can say ciliary sulcus implantation seems to be more advantageous than pars plana implantation.

It can be considered that ciliary sulcus tube shunt placement may cause chronic intraocular inflammation or pigment release due to the close contact between the tube and the iris. We did not notice an abnormal intraocular inflammation, posterior synechiae formation or pigment dispersion during the follow-up period in any eye. Also in the previous reports, generally, marked inflammation or pigment dispersion has not been mentioned after ciliary sulcus tube shunt implantation. However, Bayer et al. [18] reported marked postoperative intraocular inflammation in one of their 3 uveitic glaucoma patients underwent ciliary sulcus tube shunt placement.

In the current study, in the follow-up period, tube obstruction developed in two patients and it was due to vitreous incarceration into the tube opening. These two patiens had aphakic glaucoma. Aphakia can be considered as a contributing factor in emerging of this complication. The presence of the IOL serves as a barrier against forward movement of the vitreous gel. However, it should be noted that, vitreous incarceration after ciliary sulcus tube shunt placement has also been reported in pseudophakic eyes without an intact posterior capsule [27]. In our study, there were 6 eyes diagnosed with aphakic glaucoma. Although vitreous was not seen in the AC or pupillary area in any of them during the surgery, increase in IOP occurred in 2 eyes during the follow-up period due to vitreous incarceration. Tube obstruction was releived successfully with anterior vitrectomy in both eyes.

Limitations of our study include retrospective study design, short follow-up period, non-availability of the corneal endothelial cell density data and the lack of control group. However, the major strength of our study is the sample size. To the best of our knowledge, current study is the largest series in the literature in respect of ciliary sulcus AGV implantation.

Conclusion

Ciliary sulcus can be considered as a potential space for the tube shunt placement in aphakic/pseudophakic eyes undergoing GDD surgery. Our short-term results support the efficacy and safety of this surgical modality. However, further long-term prospective, randomized control trials comparing ciliary sulcus and AC tube shunt placement are needed.

Declarations

Conflicts of interest/competing interests

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Funding

No funding was received for conducting this study.

Ethics approval

Approval was obtained from the ethics committee of Dokuz Eylul University. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Consent to participate

Nonapplicable due to the retrospective design.

Consent to publish

Nonapplicable due to the retrospective design.

Data and/or Code availability

Data used in this study are available upon requests.

Authors’ contribution

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Gul Arikan, Betul Akbulut, Canan Asli Utine, Ziya Ayhan, Mahmut Kaya, Taylan Ozturk and Uzeyir Gunenc. The first draft of the manuscript was written by Gul Arikan and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Figures

Figure 1

Anterior segment photograph of a pseudophakic eye diagnosed with primary angle closure glaucoma. The tube tip is seen at the pupillary margin in the supero-temporal quadrant.

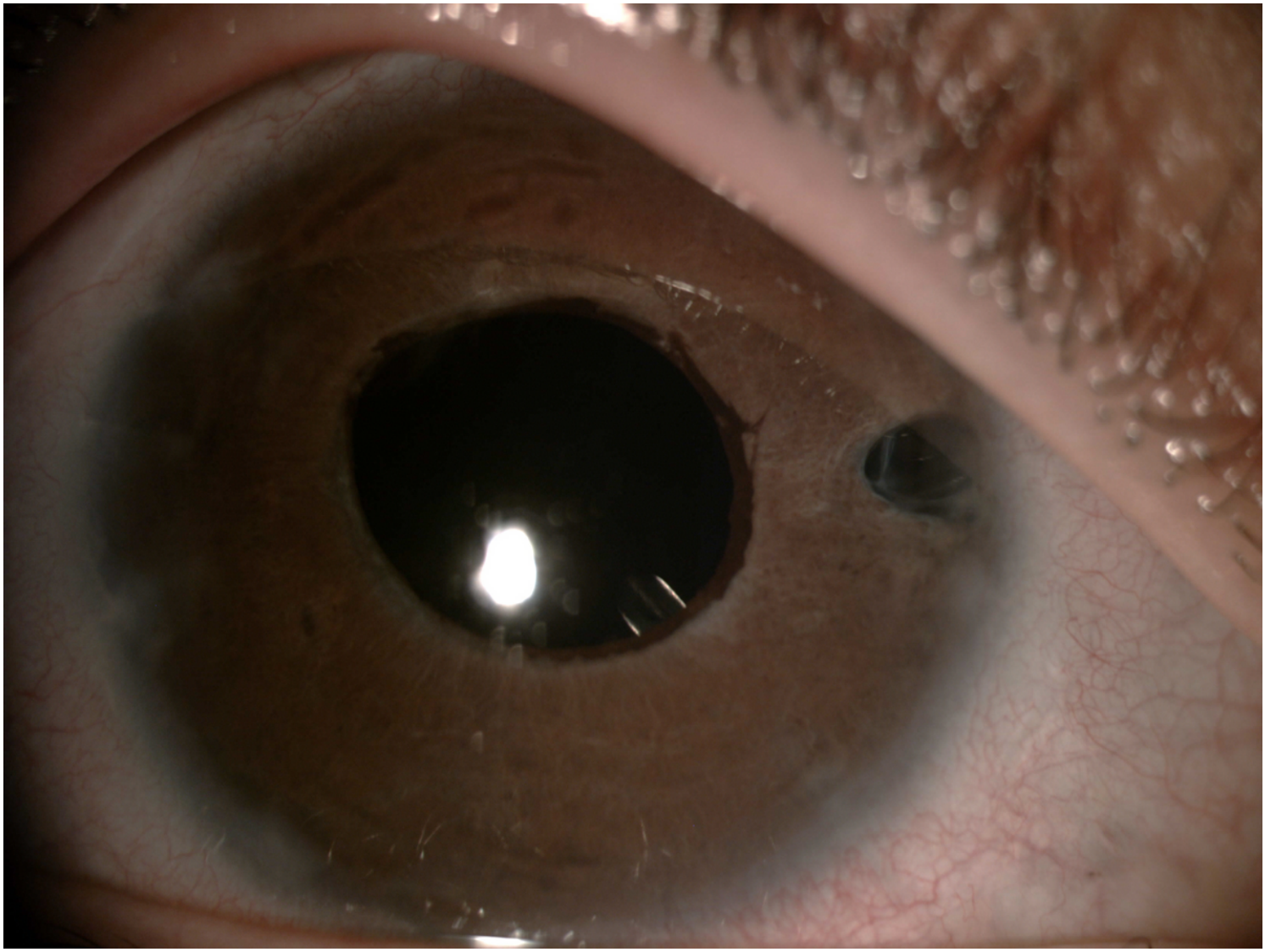

Figure 2

Anterior segment photograph of a girl diagnosed with aphakic glaucoma. The tube tip is seen at the pupillary margin in the infero-temporal quadrant.

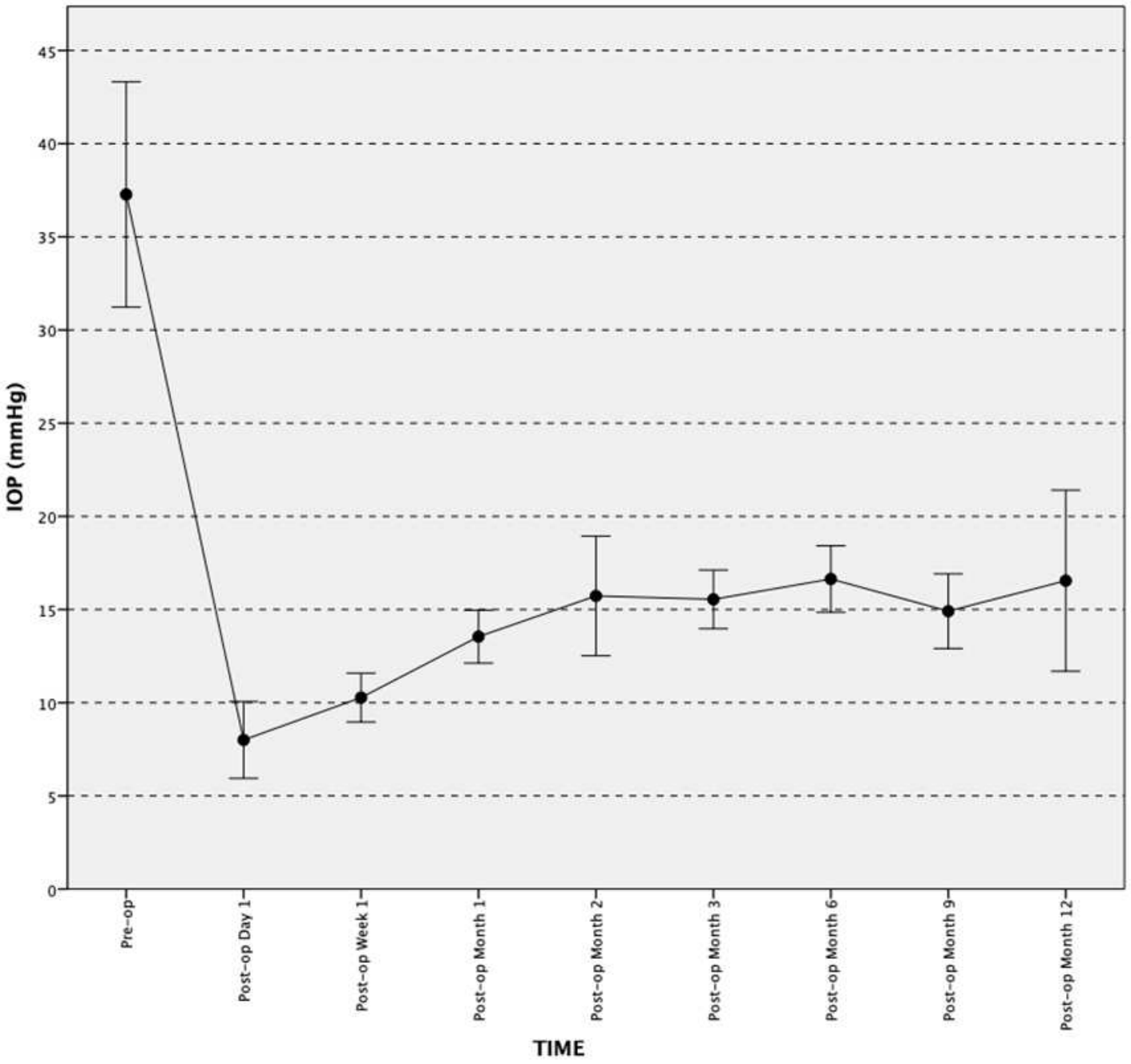

Figure 3

The mean preoperative and postoperative intraocular pressure levels. Error bars indicate standard deviations.

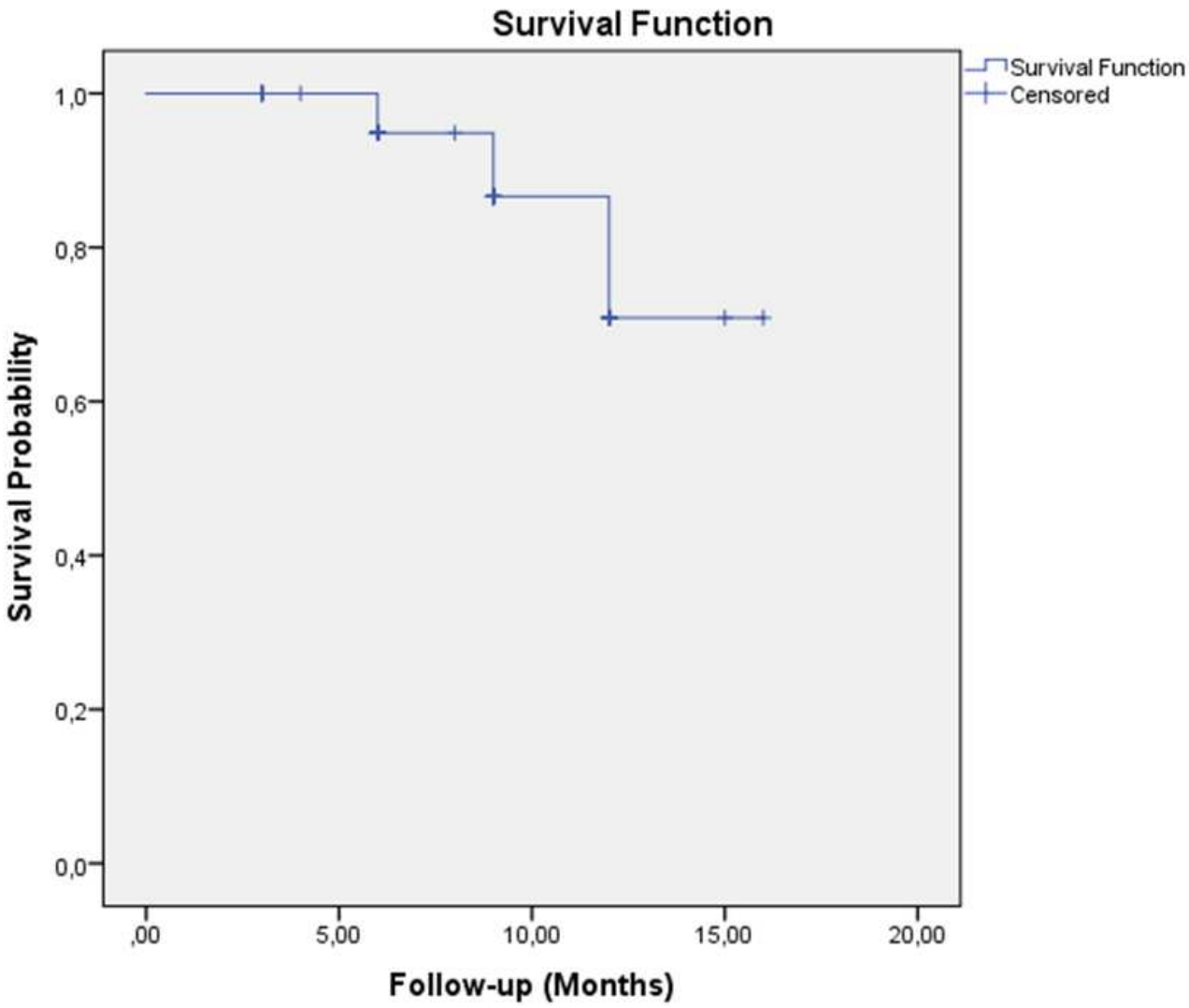

Figure 4

Kaplan-Meier survival curve. The success rates were 94.9 % at 6 months and 70.9 % at 12 months.