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REVIEW ARTICLE

The Results of the Use of Ahmed Valve in Refractory Glaucoma Surgery

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ABSTRACT

The treatment of refractory glaucoma (RG) is challenging. The commonly adopted strategy in RG treatment is a glaucoma drainage device (GDD) implantation, which despite its radical nature may not always provide the desired intraocular pressure (IOP) levels for a long term. This review is based on the scientific literature on Ahmed glaucoma valve (AGV) implantation for refractory glaucoma. The technique of AGV implantation is described and data for both the types, FP7 and FP8 performance are presented. The outcome with adjunct anti-metabolite and anti-VEGF drugs are also highlighted. An insight is given about experimental and histological examinations of the filtering bleb encapsulation. The article also describes various complications and measures to prevent them.

Keywords: Ahmed glaucoma valve, Antimetabolites, Anti-VEGF drugs, Postoperative complications, Refractory glaucoma.

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INTRODUCTION

Glaucoma is the leading cause of irreversible blindness worldwide.[1] The actual problem is the treatment of glaucoma refractory to medical treatment, laser and filtering operations. Mostly, refractory glaucoma patients include those with a previous failed trabeculectomy, neovascular glaucoma (NVG), uveal, aphakic and pseudophakic glaucoma.[2-4]

Common surgical treatments for refractory glaucoma are fistulizing operations and glaucoma drainage device (GDD) implantation. Perhaps, the most common GDD used in refractory glaucoma (RG) surgery is Ahmed glaucoma valve (AGV), which was developed in 1993. Among fistulizing surgeries, trabeculectomy remains the gold standard for most cases of glaucoma worldwide;[5] but, in cases of RG, it retains its effectiveness in the short term and over time often additional medications or surgeries are required.[6-11] Furthermore, trabeculectomy is associated with a high incidence of early and late postoperative complications.[12] Drainage operations, the principle of which was proposed in 1912 by Zorab,[13] have been used since long for RG surgery. Valved and valveless drainage devices available are Molteno (Molteno Ophthalmic Ltd., New Zealand), Baerveldt (Advanced Medical Optics, USA), Ahmed (New World Medical Inc., Rancho Cucamonga, CA, USA) and Krupin (Hood Laboratories, USA). Ahmed and Baerveldt implants are the most frequently used among these drainage devices.[14]

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EFFECTIVENESS OF AHMED GLAUCOMA VALVE

The AGV was launched in 1993 as the first GDD with a unidirectional valve mechanism contributing to the prevention of postoperative hypotension.[15] Currently, there are two models of AGV which differ in their surface areas: FP8 (96 mm^2) is used in children and FP7 (184 mm^2) is usually used in adults.

It has been hypothesized that large drainage devices increase the encapsulation area and, thus, provide a high degree of intraocular pressure (IOP) drop.[16] In a prospective study by Lloyd et al,[17] a comparison of Baerveldt valve with sizes 350 and 500 mm^2 showed no difference in efficacy and visual results. Kang and Kee[18] claimed that there is an upper limit of increase in the drainage surface area when a beneficial effect on IOP is not marked. In their study, Koh et al[19] did not observe any significant difference in effectiveness of FP8 and FP7 implantation. At a 3-year follow-up, the efficacy was 79.2% for FP8 and 72.7% for FP7, which was comparable with other studies.[19]

The FP7 type of AGV is preferred for use in the eyes of adult patients. However, the implantation of AGV FP7 model is a challenging task in patients with small anteroposterior dimensions of eyes, or if there is scarring of the conjunctiva, due to previous surgeries or inflammatory diseases of the eye. In such eyes, a large implant may lead to various complications, such as extrusion, discomfort and surgical wound dehiscence.[20] For such cases, the FP8 model may be preferable.

According to different authors, the AGV implantation is considered an effective treatment option for patients with RG and the success varies in a wide range—from 43 to 83.6%.[14,15,21-25]

Coleman et al determined the efficacy of AGV implantation in 78% of cases at 12 months after surgery.[15] Hu et al studied patients from Korea, with 6-month observation period and established efficacy in 80% of cases.[11] Das et al reported that the efficacy of AGV implantation in India 12 months postoperatively was 53% which reduced to 43% in 2 years.[26] Shah et al analyzed the results of AGV implantation in adult Arab population with RG in Oman and reported 12% absolute and 78% relative success of IOP compensation at 6 months.[27] Ishida and Netland[28] reported that African American patients were more often faced with implant failure, especially in NVG and previously operated glaucoma. In general, according to the literature, the efficacy of the tubular drainage devices is reduced by about 10% within 1 year, and, by 5 years of follow-up, implants operate effectively in about 50% of cases only.[29,30]

Encapsulation of the Filtering Bleb

The efficacy of a bypass glaucoma surgery depends largely on formation of a semipermeable capsule around the drainage device body, which determines the rate of intraocular fluid resorption and, thus, the degree of IOP decrease.[16] Formation of an encapsulated cyst of the filtering bleb is related to late complications of the AGV implant. According to different authors, the occurrence of encapsulated cyst formation varies from 5 to 30%, depending on the period of observation and patient selection. According to a retrospective analysis by Lima et al, such cysts after AGV implantation were formed in 14.7% of cases.[23] Lai et al observed 65 eyes with an AGV implant and noted encapsulated filtering blebs in 16 cases (16/65; 24.6%).[30]

Causes of excessive scarring and encapsulation of the filtering bleb are not completely studied. It is believed that the formation of the encapsulated filtering bleb depends largely on the properties of an implant, namely, its size, shape, surface of the biomaterial, which leads to adhesion and proliferation of fibroblasts.[31] As per the reported literature, the capsule wall in cases of unsuccessful AGV implant is macroscopically thicker than the wall of an encapsulated filtering bleb after trabeculectomy. However, histologically there is no difference between them.[32] It is known that the wall of the encapsulated filtering bleb after AGV implantation is divided macroscopically and histologically into two layers. The outer surface is roughly vascularized, while the inner surface is smooth due to the densely packed compressed collagen fibers and activated myofibroblasts.[33] Recent studies of a filtering bleb carried out using the optical coherence tomography of the anterior segment (ASOCT) of the eye found out that after a successful, functional AGV implantation, the wall of the filtering bleb was much thinner compared to a dysfunctional implant.[34]

Lee et al conducted a histological examination of the fibrous capsule around AGV implanted with amniotic membrane in the rabbit eyes. A fibrous capsule consisting of compact collagen fibers with minimal vascularization was seen in the control group. In contrast, the study group had a thinner myofibroblasts layer with disorganized collagen fibers in the fibrous capsule. The authors established that the use of an additional amniotic membrane may reduce the risk of encapsulation by forming a loose thin capsule around the AGV.[35]

Antimetabolites and Anti-VEGF Drugs

Antimetabolite application can significantly inhibit fibrosis, and is widely used in drainage and fistulizing glaucoma surgeries.[36-38] However, several authors have not reported any effectiveness of mitomycin C (MMC) with AGV implantation, neither in the short nor in medium term follow-up.[39,40] Recently, a new method has been described to prevent the formation of the encapsulated bleb in patients with RG after AGV implant. According to this new technique, the valve plate is wrapped in a thin layer of tissue soaked in MMC (0.25–0.33 mg/ml), and then placed over the implantation area with subsequent removal of tissue after 2 to 5 minutes, and profuse washing out of the surgical field with balanced salt solution (BSS). Efficacy and encapsulation of the filtering bleb according to this new technique were respectively 89.5 and 2.6%, while in the group with the traditional method they were 70.7 and 19.5% respectively.[41]

Alvarado et al used a tubular implant with additional antimetabolite application (both intraoperatively and postoperatively) as weekly injections for 5 weeks increases the efficacy of the surgery. It is associated with a low probability of hypertensive phase (which typically occurs between 3 weeks and 6 months postoperatively) and fewer postoperative complications.[36] However, postoperative reinterventions are inconvenient and risky for patients due to a possibility of a secondary infection by micro perforation of the filtering bleb after needling.

There is a flagrant necessity to create drug delivery systems that can be installed intraoperatively to deliver antimetabolites during the wound-healing phase after the implantation of drainage devices. Schoenberg et al[42] conducted a study of two drug delivery systems integrated with the AGV, namely, a nonbiodegradable poly (2-hydroxyethyl methacrylate) system with MMC

and biodegradable poly lactic-co-glycolic acid system with 5-fluorouracil (5-FU). The authors reported a safe concentration and pattern of the antimetabolite release, reduction in thickness of the filtering bleb and fibrous capsule.

Eid et al[43] noted a positive role of intravitreal bevacizumab (IVB) in improving the effectiveness of bypass surgery of NVG. According to some studies, IVB with AGV implantation in patients with NVG reduces a number of hemorrhagic complications, but the valve efficacy remains the same; IOP values have not been fundamentally different.[44,45] Zhang et al investigated the efficacy of IVB given prior to AGV implantation in 35 patients (35 eyes) with NVG. The efficacy was 82.9, 74.1 and 71.0% in terms of 12, 24 and 36 months respectively.[46] In another study, the authors conducted a comparative study between the two groups of patients with NVG, which had IVB injection before AGV and without it. They reported the efficacy at 12 months after surgery to be 84.0% (IVB and AGV) and 64.3% (AGV) and, after 18 months, 80.0 and 53.6% respectively. Preoperative administration of IVB significantly reduces the hyphema occurrence. Iris neovascularization regression occurred 2 to 10 days after IVB injection.[47]

Implantation Technique and Complications

Pakravan et al compared the effectiveness of the AGV implantation in the upper and lower sectors. Their study showed that the effectiveness was the same, but complications (cosmetic discomfort, tube eruption, endophthalmitis, diplopia) were more marked in the lower sector.[48] A new technique of sutureless fixation of AGV using cyanoacrylate adhesive was described in 17 patients (17 eyes) with RG. The AGV efficacy was noted to be 82.2% and there was no eruption or dislocation of the valve tube. Transient hypertension, hyphema, early postoperative hypotension were seen in four cases, tube blockage with vitreous body was seen in two cases: in case, it was broken by Nd:YAG laser, while in the second case, an anterior vitrectomy was done.[49] However, a simple valve implantation regardless of the sector of the surgery often causes severe complications, such as choroid detachment, shallow anterior chamber, transscleral eruption of the tube, valve dislocation, hypotension, diplopia, decompensation of the cornea, cataract, intraocular hemorrhage, in some cases, retinal detachment, endophthalmitis.[50-52]

According to the literature sources, a choroidal detachment after valve implantation may develop in 8 to 22% of cases.[15,53] Hypotension due to choroidal effusion has a significant damaging effect on the eye and may lead to loss of vision, thus, reducing the efficacy of the surgery itself. Even after a successful implantation of a AGV, many patients may have complications in the late postoperative period, due to the proximity of the tube to the endothelial layer,[54,55] or due to contact of AGV tube with the cornea, which, according to Topouzis et al, occurs in 5% of cases.[56]

Lee et al investigated the rate of change in endothelial cells number after AGV implantation for 24 months. The average number of endothelial cell lost after AGV implantation was 5.8% within 1 month, 11.5% after 6 months, 15.3% after 12 months, 16.6% after 18 months and 18.6% after 24 months. The greatest loss of endothelial cells was 22.6% and was observed in the area of the valve tube, while in the central area of the cornea the loss was only 15.4%, even 24 months after the surgery.[57] The literature also reports a few cases of AGV tube retraction, which may develop in the long term. According to Topouzis et al, the occurrence of this complication was seen in one in 31 patients,[56] whereas Budenz et al reported it in one in 413 patients.[14] Movement of the tube may occur due to loosening of the nonabsorbable suture, its gradual sagging and/or marked proliferation of fibroblasts around the valve plate.[58] One of the known complications of AGV implantation is erosion of the tube through the sclera and conjunctiva. Previously, transcorneal dislocation of the AGV tube was described.[59] Chances of tube erosion through the conjunctiva can be reduced by coating the tube with either of the graft materials *viz* sclera,[60] scleromeninx,[61] fascia,[62] pericardium[63] and autologous sclera.[64] In one study, a comparative analysis of application of various coating materials for GDD tube, donor sclera, pericardium and scleromeninx, showed no dependence of the valve tube erosion on the graft tissue.[65] Furthermore, suturing for graft fixation might introduce an infection and cause subsequent melting and rejection of the graft.[66] Fixation of the graft using fibrin glue has been reported to be safer and more efficient as compared to suture fixation.[67]

Inflammatory and/or immunologically mediated melting of self-tissue or the donor graft and subsequent mechanical damage by the underlying valve tube of the overlying conjunctiva lies at the heart of protruding mechanism of the valve tube erosion.[68] The bare tube is coated with self-conjunctiva, donor sclera, amniotic membrane, buccal mucosa, etc.[69] However, if these techniques are unsuccessful, then the valve should be explanted. Hu et al described four cases of valve explantation 1.5 to 9 months after the surgery due to the conjunctival erosion in three cases, and constant diplopia in one case.[70] Sibayan and Latina described a technique by covering a fistula formed at the site of the silicone tube in the cornea and sclera, with a treated

pericardium after valve explantation.[71] The followers of this technique, Yoo et al observed their patients for 26 months and reported no complications, such as rejection or melting of the pericardium, direct filtration, wound infection and endophthalmitis.[72]

Endophthalmitis is a rare complication after GDD implantation and occurs in 0.8 to 6.3% of cases.[17, 73,74] In particular, Morad et al reported three cases of endophthalmitis after AGV implantation, two of their cases were associated with tube erosion and subsequent infection. Explantation of the graft, vitrectomy and intravitreal injection of antibiotics resulted in inflammation relief.[74]

Analysis of the published data suggests that AGV implantation has proved itself as an effective surgical modality for refractory glaucoma. It is safe to conclude that the number of successful AGV implants outnumbers the complicated or failed cases.

REFERENCES

1. Quigley HA, Broman AT. The number of people with glaucoma worldwide in 2010 and 2020. Br J Ophthalmol 2006 Mar;90(3):262-267.
2. The Fluorouracil Filtering Surgery Study Group. Five-year follow-up of the Fluorouracil Filtering Surgery Study. Am J Ophthalmol 1996 Apr;121(4):349-366.
3. Broadway DC, Grierson I, Hitchings RA. Local effects of previous conjunctival incisional surgery and subsequent outcome of filtration surgery. Am J Ophthalmol 1998 Jun;125(6):805-818.
4. Minckler DS, Francis BA, Hodapp EA, Jampel HD, Lin SC, Samples JR, Smith SD, Singh K. Aqueous shunts in glaucoma. A report by the American Academy of Ophthalmology. Ophthalmol 2008 Jun;115(6):1089-1098.
5. Mosaed S, Minckler DS. Aqueous shunts in the treatment of glaucoma. Expert Rev Med Devices 2010 Sep;7(5):661-666.
6. Iwao K, Inatani M, Seto T, Takihara Y, Ogata-Iwao M, Okinami S, Tanihara H. Long-term outcomes and prognostic factors for trabeculectomy with mitomycin C in eyes with uveitic glaucoma: A retrospective cohort study. J Glaucoma 2014 Feb;23(2):88-94.
7. Allen RC, Bellows AR, Hutchinson BT, Murphy SD. Filtration surgery in the treatment of neovascular glaucoma. Ophthalmol 1982 Oct;89(10):1181-1187.
8. Heuer DK, Gressel MG, Parrish RK 2nd, Anderson DR, Hodapp E, Palmberg PF. Trabeculectomy in aphakic eyes. Ophthalmol 1984 Sep;91(9):1045-1051.
9. Syed HM, Law SK, Nam SH, Li G, Caprioli J, Coleman A. Baerveldt-350 implant versus Ahmed valve for refractory glaucoma: A case-controlled comparison. J Glaucoma 2004 Feb;13(1):38-45.
10. Taglia DP, Perkins TW, Gangnon R, Heatley GA, Kaufman PL. Comparison of the Ahmed glaucoma valve, the Krupin eye valve with disk, and the double-plate Molteno implant. J Glaucoma 2002 Aug;11(4):347-353.
11. Hu C, Lee Y, Hong Y. Ahmed glaucoma valve implant in refractory glaucoma. J Korean Ophthalmol Soc 1997;38(2): 259-266.
12. Nakatake S, Yoshida S, Nakao S, Arita R, Yasuda M, Kita T, Enaida H, Ohshima Y, Ishibashi T. Hyphema is a risk factor for failure of trabeculectomy in neovascular glaucoma: A retrospective analysis. BMC Ophthalmol 2014 Apr 26;14:55.
13. Zorab A. The reduction of tension in chronic glaucoma. Ophthalmoscope 1912;10:258-261.
14. Budenz DL, Barton K, Feuer WJ, Schiffman J, Costa VP, Godfrey DG, Buys YM; Ahmed Baerveldt Comparison Study Group. Treatment outcomes in the Ahmed Baerveldt Comparison Study after 1 year of follow-up. Ophthalmol 2011 Mar;118(3):443-452.
15. Coleman AL, Hill R, Wilson MR, Choplin N, Kotas-Neumann R, Tam M, Bacharach J, Panek WC. Initial clinical experience with the Ahmed glaucoma valve implant. Am J Ophthalmol 1995Jul;120(1):23-31.
16. Schwartz KS, Lee RK, Gedde SJ. Glaucoma drainage implants: A critical comparison of types. Curr Opin Ophthalmol 2006 Apr;17(2):181-189.
17. Lloyd MA, Baerveldt G, Fellenbaum PS, Sidoti PA, Minckler DS, Martone JF, LaBree L, Heuer DK. Intermediate-term results of a randomized clinical trial of the 350-versus the 500-mm2 Baerveldt implant. Ophthalmol 1994;101(8): 1456- 1463.
18. Kang SH, Kee C. The effectiveness of surface area extension with pericardial membrane in Ahmed glaucoma valve implant surgery. J Korean Ophthalmol Soc 2002 Nov;43(11): 2196-2201.
19. Koh KM, Hwang YH, Jung JJ, Sohn YH, Kim HK. Comparison of the outcome of silicone Ahmed glaucoma valve implantation with a surface area between 96 and 184 mm² in adult eyes. Korean J Ophthalmol 2013 Oct;27(5): 361-367.
20. Smith SL, Starita RJ, Fellman R, Lynn JR. Early clinical experience with the Baerveldt 350-mm2 glaucoma implant and associated extraocular muscle imbalance. Ophthalmol 1993 Jun;100(6):914-918.
21. Souza C, Tran DH, Loman J, Law SK, Coleman AL, Caprioli J. Long-term outcomes of Ahmed glaucoma valve implantation in refractory glaucomas. Am J Ophthalmol 2007 Dec;144(6):893-900. Epub 2007 Oct 4.
22. Papadaki TG, Zacharopoulos IP, Pasquale LR, Christen WB, Netland PA, Foster CS. Long-term results of Ahmed glaucoma valve implantation for uveitic glaucoma. Am J Ophthalmol 2007 Jul;144(1):62-69. Epub 2007 May 9.
23. Lima FE, Magacho L, Carvalho DM, Susanna R Jr, Avila MP. A prospective, comparative study between endoscopic cyclophotocoagulation and the Ahmed drainage implant in refractory glaucoma. J Glaucoma 2004 Jun;13(3):233-237.
24. Christakis PG, Kalenak JW, Zurakowski D, Tsai JC, Kammer JA, Harasymowycz P, Ahmed II. The Ahmed versus Baerveldt study: one-year treatment outcomes. Ophthalmol 2011 Nov;118(11):2180-2189.
25. Quaranta L, Riva I, Floriani IC. Outcomes of using a sutureless bovine pericardial patch graft for Ahmed glaucoma valve implantation. Eur J Ophthalmol 2013 Sep-Oct;23(5):738-742.
26. Das JC, Chaudhuri Z, Sharma P, Bhomaj S. The Ahmed glaucoma valve in refractory glaucoma: Experiences in Indian eyes. Eye (Lond) 2005 Feb;19(2):183-190.
27. Shah MR, Khandekar RB, Zutshi R, Mahrooqi R. Short term outcome of Ahmed glaucoma valve implantation in management of refractory glaucoma in a tertiary hospital in Oman. Oman J Ophthalmol 2013 Jan;6(1):27-32.

28. Ishida K, Netland PA. Ahmed glaucoma valve implantation in African American and white patients. Arch Ophthalmol 2006 Jun;124(6):800-806.
29. Patel S, Pasquale L. Glaucoma drainage devices: a review of the past, present and future. Semin Ophthalmol 2010 Sep-Nov;25(5-6):265-270.
30. Lai JS, Poon AS, Chua JK, Tham CC, Leung AT, Lam DS. Efficacy and safety of the Ahmed glaucoma valve implant in Chinese eyes with complicated glaucoma. Br J Ophthalmol 2000 Jul;84(7):718-721.
31. Hill RA, Pirouzian A, Liaw L. Pathophysiology of and prophylaxis against late ahmed glaucoma valve occlusion. Am J Ophthalmol 2000 May;129(5):608-612.
32. Bae K, Suh W, Kee C. Comparative study of encapsulated blebs following Ahmed glaucoma valve implantation and trabeculectomy with mitomycin-C. Korean J Ophthalmol 2012 Aug;26(4):265-270.
33. Thieme H, Choritz L, Hofmann-Rummelt C, Schloetzer-Schrehardt U, Kottler UB. Histopathologic findings in early encapsulated blebs of young patients treated with the Ahmed glaucoma valve. J Glaucoma 2011 Apr-May;20(4):246-251.
34. Jung KI, Lim SA, Park HY, Park CK. Visualization of blebs using anterior-segment optical coherence tomography after glaucoma drainage implant surgery. Ophthalmol 2013 May;120(5):978-983.
35. Lee JW, Park WY, Kim EA, Yun IH. Tissue response to implanted Ahmed glaucoma valve with adjunctive amniotic membrane in rabbit eyes. Ophthalmic Res 2014;51(3):129-139.
36. Alvarado JA, Hollander DA, Juster RP, Lee LC. Ahmed valve implantation with adjunctive mitomycin C and 5-fluorouracil: long-term outcomes. Am J Ophthalmol 2008 Aug;146(2):276-284.
37. Lusthaus J, Kubay O, Karim R, Wechsler D, Booth F. Primary trabeculectomy with mitomycin C: safety and efficacy at 2 years. Clin Experiment Ophthalmol 2010 Dec;38(9):831-838.
38. Al-Mobarak F, Khan AO. Two-year survival of Ahmed valve implantation in the first 2 years of life with and without intraoperative mitomycin-C. Ophthalmol 2009 Oct;116(10):1862-1865.
39. Costa VP, Azuara-Blanco A, Netland PA, Lesk MR, Arcieri ES. Efficacy and safety of adjunctive mitomycin C during Ahmed Glaucoma valve implantation: a prospective randomized clinical trial. Ophthalmol 2004 Jun;111(6):1071-1076.
40. Kurnaz E, Kubaloglu A, Yilmaz Y, Koytak A, Ozerturk Y. The effect of adjunctive Mitomycin C in Ahmed glaucoma valve implantation. Eur J Ophthalmol 2005 Jan-Feb;15(1):27-31.
41. Zhou M, Wang W, Huang W, Zhang X. Use of Mitomycin C to reduce the incidence of encapsulated cysts following Ahmed glaucoma valve implantation in refractory glaucoma patients: a new technique. BMC Ophthalmol 2014 Sep 6;14:107.
42. Schoenberg E, Blake AF. Swann, Parlin A, et al. Effect of two novel sustained-release drug delivery systems on bleb fibrosis: An In Vivo glaucoma drainage device study in a rabbit model. Transl Vis Sci Technol 2015 May;4(3):4. eCollection 2015.
43. Eid TM, Radwan A, el-Manawy W, el-Hawary I. Intravitreal bevacizumab and aqueous shunting surgery for neovascular glaucoma: safety and efficacy. Can J Ophthalmol 2009 Aug;44(4):451-456.
44. Zhou M, Xu X, Zhang X, Sun X. Clinical outcomes of Ahmed glaucoma valve implantation with or without intravitreal Bevacizumab pretreatment for Neovascular Glaucoma: a systematic review and meta-analysis. J Glaucoma 2015 2015 Feb 25. [Epub ahead of print].
45. Sahyoun M, Azar G, Khoueir Z, Antoun J, Kourie H, Nehme J, Jalkh A. Long-term results of Ahmed glaucoma valve in association with intravitreal bevacizumab in neovascular glaucoma. J Glaucoma 2015 Jun-Jul;24(5):383-388.
46. Zhang H, Yang Y, Xu Y, Yang R, Wang B, Hu J. Intravitreal bevacizumab and Ahmed glaucoma valve implantation in patients with neovascular glaucoma. Int J Ophthalmol 2014 Oct 18;7(5):837-842.
47. Zhou MW, Wang W, Huang WB, Chen SD, Li XY, Gao XB, Zhang XL. Adjunctive with versus without intravitreal bevacizumab injection before Ahmed glaucoma valve implantation in the treatment of neovascular glaucoma. Chin Med J (Engl) 2013;126(8):1412-1417.
48. Pakravan M, Yazdani S, Shahabi C, Yaseri M. Superior versus inferior Ahmed glaucoma valve implantation. Ophthalmol 2009 Feb;116(2):208-213.
49. García-Delpech S, Sanz-Marco E, Martinez-Castillo S, López-Prats MJ, Udaondo P, Salom D, Díaz-Llopis M. Ahmed valve, suture-less implantation: a new approach to an easier technique. J Glaucoma 2013 Dec;22(9):750-756.
50. Coats DK, Paysse EA, Orenga-Nania S. Acquired pseudo-Brown's syndrome immediately following Ahmed valve glaucoma implant. Ophthalmic Surg Lasers 1999 May;30(5): 396-397.
51. Hermann C, Pillunat K, Pillunat LE. Retinal hemorrhages after Ahmed glaucoma valve implantation. Ophthalmol 2013 Oct;110(10):978-981.
52. Kaya M, Ozbek Z, Yaman A, Durak I. Long-term success of ahmed glaucoma valve in refractory glaucoma. Int J Ophthalmol 2012;5(1):108-112.
53. Al-Aswad L, Netland P, Bellows AR, Ajdelsztajn T, Wadhwani RA, Ataher G, Hill RA. Clinical experience with the double-plate Ahmed glaucoma valve. Am J Ophthalmol 2006 Feb;141(2):390-391.
54. Law SK, Coleman AL, Caprioli J. Dynamic tube movement of Amhed glaucoma valve. J Glaucoma 2009 Oct-Nov;18(8): 628-631.
55. Bersudsky V, Trevino A, Rumelt S. Management of endothelial decompensation because of glaucoma shunt tube touch by descemet membrane endothelial keratoplasty and tube revision. Cornea 2011 Jun;30(6):709-711.
56. Topouzis F, Coleman A, Choplin N, Bethlem MM, Hill R, Yu F, Panek WC, Wilson MR. Follow-up of the original cohort with the Ahmed glaucoma valve implant. Am J Ophthalmol 1999 Aug;128(2):198-204.
57. Lee EK, Yun YJ, Lee JE, Yim JH, Kim CS. Changes in corneal endothelial cells after Ahmed glaucoma valve implantation: 2-year follow-up. Am J Ophthalmol 2009 Sep;148(3): 361-367.
58. Lloyd MA, Baerveldt G, Nguyen QH, Minckler DS. Long-term histologic studies of the Baerveldt implant in a rabbit model. J Glaucoma 1996 Oct;5(5):334-339.
59. Al-Torbak A, Edward DP. Transcorneal tube erosion of an Ahmed valve implant in a child. Arch Ophthalmol 2001 Oct;119(10):1558-1559.
60. Freedman J. Scleral patch grafts with Molteno setons. Ophthalmic Surg 1987 Jul;18(7):532-534.

61. Brandt JD. Patch grafts of dehydrated cadaveric dura mater for tube-shunt glaucoma surgery. Arch Ophthalmol 1993 Oct;111(10):1436-1439.
62. Tanji TM, Lundy DC, Minckler DS, Heuer DK, Varma R. Fascia lata patch graft in glaucoma tube surgery. Ophthalmol 1996 Aug;103(8):1309-1312.
63. Raviv T, Greenfield DS, Liebman JM, Sidoti PA, Ishikawa H, Ritch Ral. Pericardial patch grafts in glaucoma implant surgery. J Glaucoma 1998 Feb;7(1):27-32.
64. Aslanides IM, Spaeth GL, Schmidt CM, Lanzl IM, Gandham SB. Autologous patch graft in tube shunt surgery. J Glaucoma 1999 Oct;8(5):306-309.
65. Smith MF, Doyle JW, Ticrney JW Jr. A comparison of glaucoma drainage implant tube coverage. J Glaucoma 2002 Apr;11(2):143-147.
66. Ainsworth G, Rotchford A, Dua HS, King AJ. A novel use of amniotic membrane in the management of tube exposure following glaucoma tube shunt surgery. Br J Ophthalmol 2006 Apr;90(4):417-419.
67. Choudhari NS, Neog A, Sharma A, Iyer GK, Srinivasan B. Our experience of fibrin sealant-assisted implantation of Ahmed glaucoma valve. Ind J Ophthalmol 2013 Jan-Feb;61(1):23-27.
68. Heuer DK, Budenz DL, Coleman A. Aqueous shunt tube erosion. J Glaucoma 2001 Dec;10(6):493-496.
69. Low SA, Rootman DB, Rootman DS, Trope GE. Repair of eroded glaucoma drainage devices: Mid-term outcomes. J Glaucoma 2012 Dec;21(9):619-622.
70. Hu WD, Pro MJ, Fudemberg SJ, Moster MR. Explantation of the novel Ahmed glaucoma valve M4 implant. J Glaucoma 2015 Feb;24(2):e1-4.
71. Sibayan SA, Latina MA. The use of processed pericardium in the repair of corneo-scleral fistulas. Ophthalmic Surg Lasers 1997 Apr;28(4):334-335.
72. Yoo C, Kwon SW, Kim YY. Pericardium plug in the repair of the corneoscleral fistula after Ahmed glaucoma valve explantation. Korean J Ophthalmol 2008 Dec;22(4):268-271.
73. Gedde SJ, Scott IU, Tabandeh H, Luu KK, Budenz DL, Greenfield DS, Flynn HW Jr. Late endophthalmitis associated with glaucoma drainage implants. Ophthalmol 2001 Jul;108(7):1323-1327.
74. Morad Y, Donaldson CE, Kim YM, Abdolell M, Levin AV. The Ahmed drainage implant in the treatment of pediatric glaucoma. Am J Ophthalmol 2003 Jun;135(6):821-829.