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Research article

Outcomes of Ahmed glaucoma valve implantation in pediatric glaucoma

Natalia N. Sadovnikova, Vladimir V. Brzheskiy, Natalia V. Prisich, Marina A. Zertsalova, Andrei Yu. Baranov

St. Petersburg State Pediatric Medical University, Saint Petersburg, Russia

BACKGROUND: In many types of pediatric glaucoma, there is no clear algorithm for surgical management. In these situations, the procedure of choice can be the implantation of various types of drainage devices.

AIM: To evaluate the outcomes of Ahmed Glaucoma Valve implantation in refractory pediatric glaucoma.

MATERIALS AND METHODS: The treatment results of 52 children (67 eyes) aged 1 month – 17 years (6.6 ± 0.6 years) with unsuccessfully operated primary congenital glaucoma, with glaucoma associated with congenital anomalies of the eyeball, with secondary glaucoma were analyzed. The surgery was considered to be effective when stable intraocular pressure (IOP) was achieved, there were no complications, and no need for repeated interventions.

RESULTS: The effect of surgery was maintained for 6 months in 97% of patients, but after 1, 2 and 3 years it decreased to 91.8%, 82%, and 73.9%, respectively, and to 42.8% after 7 years. Postoperative complications included filtering bleb encapsulation (25.3%), iris retraction to the tube with pupil dislocation (4.5%); ciliochoroidal detachment (4.5%); cataract (3.0%), conjunctival erosion with tube eruption (4.5%), endophthalmitis (1.5%), retinal detachment (6.0%), tube retraction (1.5%), hyphema (3.0%). The risk factors for an unfavorable outcome of the procedure were: an increase in the anteroposterior axis of the eyeball length by 20% or more compared to the age norm, IOP at the time of the surgery higher than 32 mm Hg, as well as previous antiglaucoma filtering procedures.

CONCLUSIONS: The implantation of the drainage device Ahmed Glaucoma Valve is indicated for refractory pediatric glaucoma in case of ineffectiveness of previous surgeries. However, it is necessary to take into account the decrease in the effectiveness of the device over time, which, combined with the possibility of complications, requires long-term follow-up of patients.

Keywords: Ahmed valve; drainage devices; congenital glaucoma; pediatric glaucoma.

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Научная статья

Клапан Ахмеда в лечении детей с рефрактерной глаукомой

Н.Н. Садовникова, В.В. Бржеский, Н.В. Присич, М.А. Зерцалова, А.Ю. Баранов

Санкт-Петербургский государственный педиатрический медицинский университет, Санкт-Петербург, Россия

Актуальность. При многих формах глаукомы у детей не предусмотрен алгоритм хирургического лечения. В этих ситуациях, а также в случаях рефрактерной глаукомы, при неэффективности хирургических вмешательств, операцией выбора может быть имплантация различных видов дренажных устройств.

Цель — оценка эффективности имплантации клапанного дренажа Ahmed Glaucoma Valve при рефрактерной глаукоме у детей.

Материалы и методы. Проанализированы результаты лечения 52 детей (67 глаз) в возрасте от 1 мес. до 17 лет (6,6 ± 0,6 года) с безуспешно оперированной первичной врождённой глаукомой, глаукомой на фоне врождённых аномалий глазного яблока, вторичной глаукомой. Критерием успеха хирургического лечения стала стойкая нормализация офтальмотонуса, отсутствие осложнений и потребности в повторных вмешательствах.

Результаты. Эффект операции сохранялся в течение 6 мес. у 97 % пациентов, однако через 1, 2 и 3 года он снижался до 91,8, 82, и 73,9 % соответственно и до 42,8 % через 7 лет. Послеоперационные осложнения включали инкапсуляцию фильтрационной подушки (25,3 %), ретракцию радужки к трубке с корэктопией (4,5 %), цилиохориоидальную отслойку (4,5 %), катаракту (3,0 %), эрозию конъюнктивы с прорезыванием трубки (4,5 %), эндофтальмит (1,5 %), отслойку сетчатки (6,0 %), ретракцию трубки (1,5 %), гифему (3,0 %). Факторами риска неблагоприятного исхода вмешательства оказались: увеличение переднезаднего отрезка глазного яблока по сравнению с возрастной нормой на 20 % и более, офтальмотонус на момент операции более 32 мм рт. ст., а также перенесённые ранее антиглаукомные операции фильтрующего типа.

Заключение. Имплантация дренажного устройства Ahmed Glaucoma Valve показана при рефрактерной детской глаукоме в случае неэффективности предшествующих операций. Однако необходимо учитывать снижение эффективности устройства со временем, что в сочетании с возможностью осложнений требует длительного динамического наблюдения пациентов.

Ключевые слова: клапан Ахмеда; дренажные устройства; врождённая глаукома; глаукома у детей.

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ЭКО•ВЕКТОР

BACKGROUND

Pediatric glaucoma is a known heterogeneous group of diseases with the potential to cause blindness, and most of them are refractory to drug therapy. It includes primary congenital glaucoma, glaucoma associated with systemic congenital diseases and anomalies of eyeball development (such as Sturge–Weber syndrome, Peters anomaly, and aniridia), and secondary glaucoma (such as uveal, steroid-induced glaucoma, glaucoma associated with retinopathy of prematurity, and aphakic and neovascular glaucoma [1–3]. Childhood glaucoma, considering its resistance to surgical and medical treatment, can be classified as refractory glaucoma [2, 4, 5]; however, more refractory forms of glaucoma can be distinguished within this refractivity.

Goniotomy and trabeculotomy are the surgeries of choice in the treatment of patients with primary congenital glaucoma. If "angular surgery" is ineffective, the surgeon proceeds to the next stages of surgical treatment, i.e., trabeculectomy and implantation of drainage devices [2–6]. As for the other types of pediatric glaucoma, no surgical algorithm has been established for many of them, and in such situations, the implantation of drainage devices often becomes the first antihypertensive surgery.

The anti-glaucoma drainage made by Antony Molteno was first implanted in a child in 1973 [7]. Since then, many studies have investigated the efficiency and complication rates of these interventions in pediatric patients [2–4, 8–16]. The drainage system Ahmed Glaucoma Valve (New World Medical, Inc., Rancho Cucamonga, CA, USA) became the most accessible for pediatric ophthalmologists. Thus, it is relevant to evaluate the efficiency of the implantation of this device in various forms of pediatric glaucoma.

The work aimed to evaluate the efficacy of Ahmed Glaucoma Valve drainage implantation in pediatric patients with refractory glaucoma.

MATERIALS AND METHODS

The results of the surgical treatment of 52 children (67 eyes), who underwent implantation of the Ahmed valve for refractory glaucoma in the Ophthalmology Department of St. Petersburg State Pediatric Medical University from 2011 to 2020, were evaluated.

All pediatric patients, depending on the form of glaucoma, were distributed into three groups, namely, primary congenital glaucoma (n = 8, 11 eyes); glaucoma associated with a congenital malformation of the eyeball (n = 17, 23 eyes), including aniridia syndrome (n = 8, 13 eyes), microspherophakia (n = 3, 4 eyes), Sturge–Weber syndrome (n = 1; 1 eye), Axenfeld–Rieger syndrome (n = 1; 1 eye), Peters anomaly (n = 1; 1 eye), and anterior segment dysgenesis with sclerocornea (n = 3; 3 eyes); and secondary glaucoma (n = 27, 33 eyes), including aphakic glaucoma (n = 10, 12 eyes), glaucoma due to retinopathy of prematurity (n = 7; 8 eyes), uveal glaucoma (n = 5; 8 eyes), glaucoma due to silicone tamponade (n = 1; 1 eye), glaucoma associated with familial exudative vitreoretinopathy (n = 1; 1 eye), and traumatic glaucoma (n = 3; 3 eyes).

Ophthalmological examination before and after surgery included visometry with maximum correction (if possible due to the child's age), biomicroscopy, gonioscopy, goniography, indirect ophthalmoscopy, tonometry (according to Maklakov, and in case of unfeasibility, with an ICare tonometer), keratometry, and ultrasonography in A and B modes. If necessary, studies, especially in young children, were performed under drug-induced sleep using sevoflurane.

Patients were followed up every 3 months within a year after surgery and then every 6 months. Instillations of topical antihypertensive drugs were added as needed to achieve the target intraocular pressure (IOP) (P_0 > 22 mm Hg, without an increase in the anteroposterior segment [APS]).

Surgical efficiency throughout the follow-up period was recorded when stable ophthalmotonus (P_0) was achieved (IOP = 6–22 mm Hg), in the absence of complications potentially leading to loss of visual functions (valve tube erosion, retinal detachment, hemorrhagic ciliochoroidal detachment, and endophthalmitis), and in the absence of the need for repeated hypotensive surgeries. Cases when revision and needling of the valve platform were required for encapsulation of the filtration bleb were not classified as having poor outcomes if the tube position remained stable and the IOP was compensated. In situations when valve replacement was required because of its dislocation or inefficiency, as well as implantation of a second drainage device, only the results of the first implantation were included in the study, and this case was also classified as a poor outcome.

The surgical technique in pediatric patients was standard and almost did not differ from the surgery in adult patients; however, some anatomical aspects of the children's eyeball were considered. The valve platform was always sutured to the sclera 8 mm aside from the limbus to reduce fibrous changes in Tenon's capsule. The length of the intraocular part of the tube was not less than 2 mm owing to the risk of its retraction with an increase in the size of the eyeball APS. In eyes with buphthalmos, a 25 G puncture was performed to avoid filtration of the intraocular fluid around the tube and to minimize postoperative hypotension. The outer part of the tube was covered with an alloplant graft to prevent tube erosion and development of infectious complications [2, 8–10]. In case of small sizes of the orbit, a canthotomy was performed for the correct position of the valve platform

Table 1. Number of patients followed-up after valve implantation

Таблица 1. Количество пациентов, наблюдавшихся после имплантации клапана

Follow-up period, months	0	6	12	24	36	48	60	72	84
Number of patients	67	65	59	56	46	39	29	29	28

in two cases. The tube was inserted into the anterior chamber parallel to the iris surface in 64 eyes, to the ciliary sulcus in three eyes, and through the flat part of the ciliary body in two eyes.

The minimum follow-up period was 6 months, while 29 pediatric patients were followed up for more than 5 years (Table 1).

RESULTS

The study included 52 pediatric patients (67 eyes; 19 girls and 33 boys) aged 1 month to 17 years old. The children were examined before and after surgery (Table 2).

The age of the patients at the time of surgery was 6.6 ± 0.6 years (1 month to 17 years), whereas pediatric patients in the group with secondary glaucoma were older (t = 2.36; p < 0.05). The mean follow-up period after valve implantation was 44.0 ± 4.9 (6–120) months. The mean IOP range before surgery was 21–42 mm Hg, and it was 12–22 mm Hg at the end of the follow-up (t = 18.8; p < 0.01). The IOP values before and after surgery were comparable in all three groups (t = 0.7–0.3, p > 0.05). The average anteroposterior size of the eyeball exceeded the age norm, at 25.0 ± 0.3 mm (19.0–29.97 mm) before surgery and did not change significantly after surgery (24.2 ± 0.6 mm), and the differences were not significant (t = 1.2, p > 0.05). In patients with congenital glaucoma, the eyeball size was larger than that in other groups (t = 4.9–4.5, p < 0.01).

In 67.2% of the cases, other anti-glaucoma surgeries were performed before implantation of the Ahmed valve (average 1.7 ± 0.2 surgeries per child). Half of the patients (35 of 67 eyes, 52.2%) underwent at least one filter-type surgery (sinus trabeculectomy). In 25 of 67 eyes (37.3%), cyclodestructive surgeries were performed before valve implantation. No patients had received implantation of drainage devices previously. The smallest number of hypotensive surgical interventions before valve implantation was performed in patients with glaucoma that developed

Table 2. Characteristics of examined patients

Таблица 2. Характеристика обследованных пациентов

Parameters	Total	Disease etiology		
		primary congenital glaucoma	glaucoma associated with congenital anomalies	secondary glaucoma
Number of patients (eyes)	52 (67)	8 (11)	17 (23)	27 (33)
Boys: number of patients (eyes)	33 (41)	8 (11)	11 (13)	14 (17)
Girls: number of patients (eyes)	19 (26)	0	6 (10)	13 (16)
Age at implantation (range)	6.6 ± 0.6 (1 month to 17 years)	4.5 ± 1.2 (9 months to 14 years)	4.9 ± 1.2 (1 month to 16 years)	8.3 ± 0.8 (9 months to 17 years)
Average follow-up period (range), months	44.0 ± 4.9 (6–120)	59.5 ± 10.2 (30–90)	26.0 ± 6.3 (6–114)	51.7 ± 7.4 (6–120)
Average intraocular pressure (P_0) before surgery, mm Hg	32.1 ± 0.6	31.4 ± 1.3	32.5 ± 0.9	31.9 ± 0.9
Average intraocular pressure (P_0) at the last examination, mm Hg	18.5 ± 0.4	19.75 ± 0.9	17.1 ± 0.5	19.1 ± 0.5
Average anteroposterior eyeball size before surgery, mm	25.0 ± 0.3	27.8 ± 0.5	23.9 ± 0.6	24.9 ± 0.4
Average anteroposterior eyeball size at the last examination, mm	24.2 ± 0.6	28.0 ± 0.7	23.3 ± 0.6	23.9 ± 0.9
Previous hypotensive surgeries:	1.7 ± 0.2	2.9 ± 0.4	0.9 ± 0.3	1.8± 0.3
• trabeculectomy	1.37 ± 1.0	2.36 ± 0.5	0.7 ± 0.9	1.3 ± 0.9
• cyclophotocoagulation	0.7 ± 0.8	0.5 ± 0.6	0.42 ± 0.6	1.05 ± 1.0

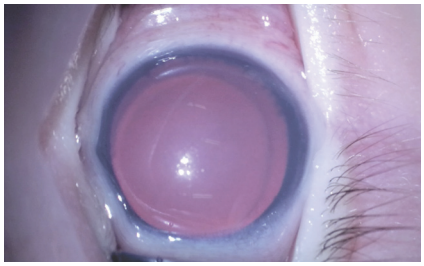

Fig. 1. The eye of a newborn child with glaucoma due to congenital aniridia
Рис. 1. Глаз новорождённого ребёнка с глаукомой на фоне врождённой аниридии

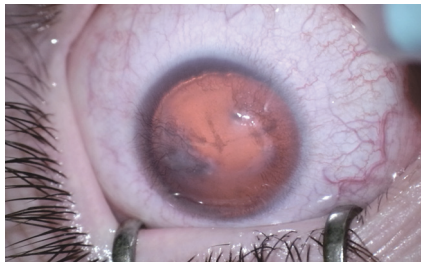

Fig. 2. The eye of a 16-year-old child with aniridic syndrome
Рис. 2. Глаз ребёнка 16 лет с аниридийным синдромом

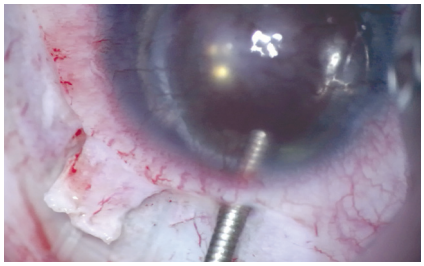

Fig. 3. The eye of a 14-year-old child with aniridic syndrome, pseudophakia with an implanted valve
Рис. 3. Глаз ребёнка 14 лет с аниридийным синдромом, артифакией с имплантированным клапаном

in presence of congenital syndromes (39.1% of eyes, an average of 0.9 surgeries in each child), and the differences with other groups were significant (t = 4.1–2.2, p < 0.05). In 16 pediatric patients (22 eyes), Ahmed valve implantation was the first hypotensive surgery. These were patients with glaucoma, in which trabeculectomy is usually ineffective, associated with aniridia syndrome (n = 7, 11 eyes) (Fig. 1–3), with aphakic glaucoma (n = 4, 5 eyes), with anterior eye dysgenesis with sclerocornea (n = 3, 3 eyes), with glaucoma associated with familial hereditary exudative vitreoretinopathy (n = 1, 1 eye), and uveal glaucoma (n = 1, 2 eyes).

According to our data, the hypotensive effect of the surgery persists for 6 months in 97% of the patients, which subsequently decreases [4, 10–14, 16]. Thus, the surgery efficiency was 91.8%, 82%, and 73.9% after 1, 2, and 3 years, respectively, and reached 42.8% after 7 years of follow-up (Fig. 4).

A comparative analysis of Ahmed valve implantation efficiency in pediatric patients was performed based on the literature data (Table 3).

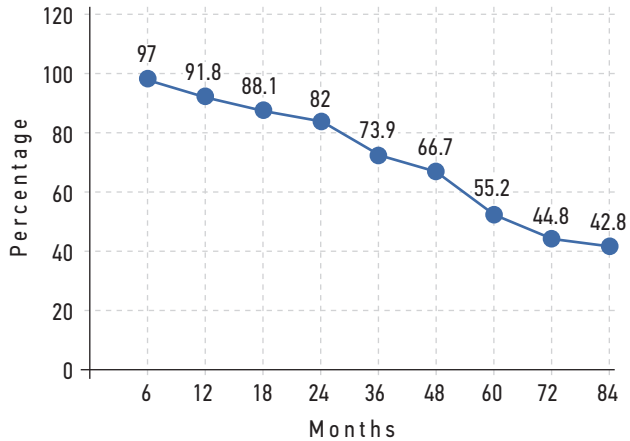

Fig. 4. Dynamics of the hypotensive effect of Ahmed valve implantation during the follow-up period
Рис. 4. Динамика гипотензивного эффекта операции имплантации клапана Ахмеда за период наблюдения

No intraoperative complications occurred during valve implantation. Postoperative complications included the following:

Table 3. Comparative results of Ahmed valve implantation in pediatric glaucoma
Таблица 3. Сравнительные результаты имплантации клапана Ахмеда при детской глаукоме

Author	Number of patients (eyes)	Mean age (years)	Previous surgery, %	Follow-up period, months	Preservation of the hypotensive effect for 1–5 years, %				
					1	2	3	4	5
O. Albis-Donado (2010) [11]	106 (128)	7.58	32.8	25.7	82	79	70	41	–
F. Al Mobarak (2009) [13]	36 (42)	0.98	100	24	74	63	–	–	–
Y. Ou (2009) [14]	19 (30)	1.8	93	57.6	63	50	50	41	33
H.K. Yang (2008) [17]	29 (34)	5.5	44.1	–	69	46	–	–	–
Y. Morad (2003) [3]	44 (60)	6	97	24.3	93	86	71	45	–
S. Balekudaru (2014) [18]	71 (71)	6.8	67	37.8	97	80	–	–	–
R. Autratta (2007) [19]	76 (76)	6.9	55.2	85.2	91	82	76	71	67
A. Chen (2015) [20]	100 (136)	7.1	30	75.6	88	–	–	–	55
K. Spiess (2021) [21]	23 (29)	2	–	85.4	68	64		54	54
M. Pakravan (2018) [16]	72 (95)	7.9	–	51.3	81	72	66	62	59
Study presented	52 (67)	6.6	67.2	44.0	92	82	74	67	55

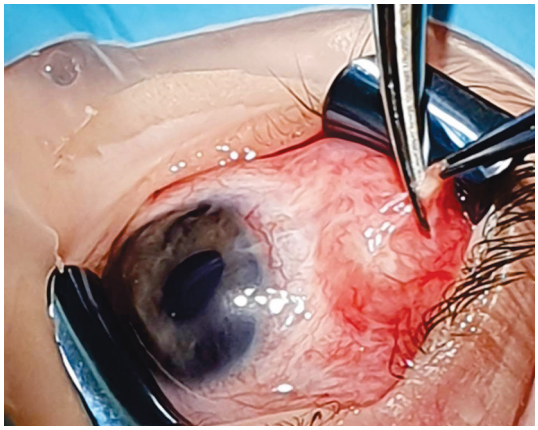

Fig. 5. Bleb encapsulation
Рис. 5. Инкапсуляция фильтрационной подушки

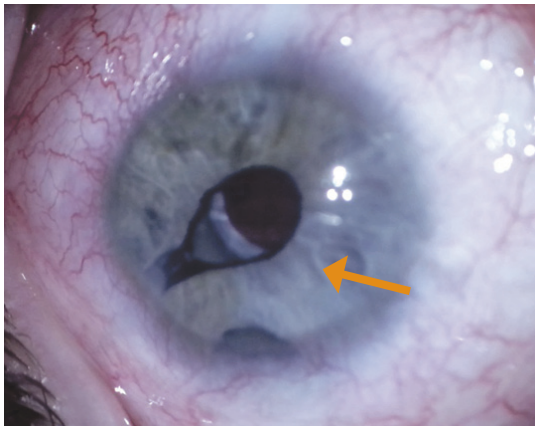

Fig. 6. Retraction of the iris to the tube (shown by the arrow)
Рис. 6. Ретракция радужки к трубке (показана стрелкой)

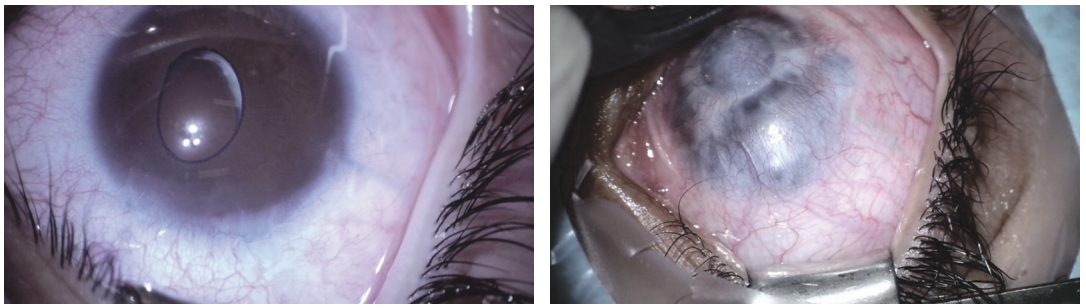

Fig. 7. Tube retraction
Рис. 7. Ретракция трубки

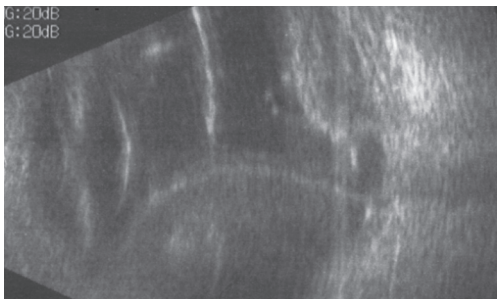

Fig. 8. Echogram of a patient with postoperative total ciliochoroidal detachment
Рис. 8. Эхограмма пациента с послеоперационной тотальной цилиохориоидальной отслойкой

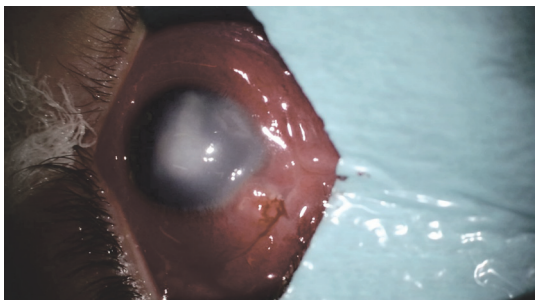

Fig. 9. The eye of a 5-year-old patient with endophthalmitis due to tube erosion 3 months after implantation of the Ahmed valve
Рис. 9. Глаз пациента 5 лет с эндофтальмитом, возникшим вследствие эрозии трубки через 3 мес. после имплантации клапана Ахмеда

- Encapsulation of the filtering bleb in 17 eyes (25.3%) (Fig. 5). In all cases, the valve platform was revised, a portion of the capsule above it was excised, while the tube position remained stable, and IOP was compensated after surgery.
- Retraction of the iris to the tube, with a change in the pupil shape in three eyes (4.5%) (Fig. 6).
- Retraction of the tube in one eye (1.5%), namely, displacement of the tube end to the limbus zone due to eyeball stretching. The valve platform was displaced anteriorly (Fig. 7).
- Ciliochoroidal detachment (Fig. 8) in the early postoperative period in three eyes (4.5%), which was stopped using conservative therapy with corticosteroids; one case required posterior scleral trepanation.
- Complicated cataract in 2 (3.0%) eyes associated with buphthalmos. Planned phacoaspiration was performed.

Tube erosion was registered in 3 (4.5%) eyes. In one case (1.5%), this led to the development of endophthalmitis in a child who, 3 months after surgery, had acute conjunctivitis associated with chickenpox (Fig. 9). In other cases, the tube was additionally covered with alloplant, and the platform position remained stable throughout the follow-up. Retinal detachment was detected in 4 (6.0%) eyes. In all cases, it was diagnosed in the late

Table 4. Postoperative complications of Ahmed valve implantation
Таблица 4. Послеоперационные осложнения имплантации клапана Ахмеда

Type of complication	Literature data, %	Study presented, %
Anterior displacement of the tube with its contact with the cornea	2–34	–
Tube retraction	3.9–8.3	1.5
Conjunctival erosion with tube eruption	1.6–7	4.6
Endophthalmitis	Single cases	2.3
Obstruction of the drainage tube by blood, fibrin, lens capsule, or vitreous body	4–13.5	–
Retraction of the iris to the tube, resulting in a change in the pupil shape	До 21	9.3
Bleb encapsulation	21–30	32.5
Mobility disorders, diplopia, and gaze limitation	1.9–7.3	–
Hypotension with P_0 <5 5 mm Hg	10–42	–
Ciliochoroidal detachment	2.1–4.2	6.8
Retinal detachment	2.2–7.1	9.3
Hemophthalmos	3.9–8	–
Cataract	Single cases	2.3
Hyphema	Single cases	–
Valve platform displacement	Single cases	2.3

Table 5. Risk factors for unfavorable outcome after Ahmed valve implantation
Таблица 5. Факторы риска развития неблагоприятного исхода после имплантации клапана Ахмеда

Risk factor	X^2	*p*
Age <1 year	0.01	>0.05
Anteroposterior segment exceeding the age norm by 20%	7.9	<0.05
Age <5 years	1.4	>0.05
Intraocular pressure >32 mm Hg	20.1	<0.05
Previous antihypertensive filter-type surgeries	7.8	<0.05
Previous non-glaucomatous surgeries	0.02	>0.05
Previous cyclodestructive surgeries	0.9	>0.05

postoperative period (i.e., after 6 months or longer) in eyes with buphthalmos, and its relationship with valve implantation was not significant.

The amount and nature of complications of drainage device implantation in pediatric patients differ significantly in various literature sources. For example, their frequency ranged from 84.6% in the study by Chen et al. [12] (44/52 eyes) up to 28.9% according to Albis-Donado et al. [11]. Table 4 presents the comparison of the incidence of complications in our study and literature [2, 3, 4, 11–16].

We also analyzed risk factors for adverse outcomes after Ahmed valve implantation in pediatric patients (Table 5). Significant factors were an increase in the eyeball APS by ⩾20% compared with the age norm, the IOP at the time of surgery was >32 mm Hg, and there was a history of anti-glaucoma-filtering surgeries.

CONCLUSION

The Ahmed Glaucoma Valve drainage device can be implanted in refractory pediatric glaucoma if previous surgeries were ineffective. In some cases, namely, with buphthalmos, aphakic, avitreal eyes, dysgenesis of the anterior segment of the eye with underdevelopment of the anterior chamber angle, this intervention is the only possible means of reducing IOP and preserving visual functions and the eyeball. In such cases, this intervention is advisable as the first surgery.

The decrease in the efficiency of the drainage device over time should be considered, as well as the possibility of complications in the late postoperative period; thus, long-term case follow-up of these patients is necessary.

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AUTHORS' INFO

***Natalia N. Sadovnikova,** Cand. Sci. (Med.), Head of Department of Ophthalmology; address: 2, Litovsckaya st., Saint Petersburg, 194100, Russia; ORCID: https://orcid.org/0000-0002-8217-4594; e-mail: natasha.sadov@mail.ru

Vladimir V. Brzheskiy, Dr. Sci. (Med.), Head of Department of Ophthalmology; ORCID: https://orcid.org/0000-0001-7361-0270; e-mail: vvbrzh@yandex.ru

* Corresponding author / Автор, ответственный за переписку

ОБ АВТОРАХ

***Наталия Николаевна Садовникова,** канд. мед. наук, заведующая офтальмологическим отделением; адрес: Россия, 194100, Санкт-Петербург, Литовская ул., д. 2; ORCID: https://orcid.org/0000-0002-8217-4594; e-mail: natasha.sadov@mail.ru.

Владимир Всеволодович Бржеский, д-р мед. наук, профессор, заведующий кафедрой офтальмологии; ORCID: https://orcid.org/0000-0001-7361-0270; e-mail: vvbrzh@yandex.ru

AUTHORS' INFO

Natalia V. Prisich, Ophthalmologist;
ORCID: https://orcid.org/0000-0001-7749-7850;
e-mail: prisichnv@rambler.ru

Marina A. Zertsalova,
Assistant of Department of Ophthalmology;
ORCID: https://orcid.org/0000-0003-4559-0051;
e-mail: mazercalova@mail.ru

Andrei Yu. Baranov,
Assistant of Department of Ophthalmology;
ORCID: https://orcid.org/0000-0002-6024-4635;
e-mail: homeandrey@rambler.ru

ОБ АВТОРАХ

Наталия Владимировна Присич, врач-офтальмолог;
ORCID: https://orcid.org/0000-0001-7749-7850;
e-mail: prisichnv@rambler.ru

Марина Андреевна Зерцалова,
ассистент кафедры офтальмологии;
ORCID: https://orcid.org/0000-0003-4559-0051;
e-mail: mazercalova@mail.ru

Андрей Юрьевич Баранов,
ассистент кафедры офтальмологии;
ORCID: https://orcid.org/0000-0002-6024-4635;
e-mail: homeandrey@rambler.ru