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Clinical Efficacy of Ciliary Ring Incision Combined with Modified Partial Pars Plana Vitrectomy for Malignant Glaucoma

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Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

ABCDEG **Jianchun Yu***
ABCDEF **Xing Chen***
BC **Danying Zhou**
AB **Jian Shen**
AB **Yanbing Wu**
AB **Qingzhu Sun**

Department of Ophthalmology, Wuxi No. 9 People's Hospital Affiliated to Soochow University, Wuxi, Jiangsu, P.R. China

* Jianchun Yu and Xing Chen contributed equally to this work

Corresponding Author: Jianchun Yu, e-mail: jiuyuanyanke@163.com
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Background: Currently, safe and effective surgical treatment of malignant glaucoma is still under investigation. This study evaluated the clinical efficacy of ciliary ring incision combined with modified partial pars plana vitrectomy in the treatment of malignant glaucoma. The technique is particularly useful in the treatment of "phakic" patients with malignant glaucoma, especially those who wish to preserve the natural lens.

Material/Methods: We retrospectively analyzed 13 cases (16 eyes) of malignant glaucoma in which patients underwent ciliary ring incision combined with modified partial pars plana vitrectomy based on follow-up data collected from May 2004 to March 2017. The data we analyzed included postoperative best-corrected visual acuity(BCVA), intraocular pressure (IOP), anterior chamber depth (ACD), optic cup changes, and surgical complications; some patients underwent visual field tracking. The mean follow-up period was 33.1±10.6 (range, 19–46) months.

Results: A statistically significant number of eyes had improved visual acuity 1 year after surgery compared with the preoperative difference (Z=–3.853, P=0.000). Increases in the mean anterior chamber depth and decreases in the mean IOP measured at the 1-week and the 1-year follow-ups were also statistically significant. There were no serious complications during the follow-up period.

Conclusions: Ciliary ring incision combined with modified partial pars plana vitrectomy for malignant glaucoma not only provided a clear and reliable intraoperative vitrectomy channel, but it also caused less disturbance of intraocular tissue structure and fewer complications. It also has the advantage of preserving the lens and avoiding further damage to the anatomy in the anterior segment of the eye.

MeSH Keywords: **Glaucoma • Models, Anatomic • Vitrectomy**

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Background

Malignant glaucoma, also known as ciliary block glaucoma or aqueous misdirection syndrome [1], typically develops after surgery in patients with primary angle-closure and primary angle-closure glaucoma. It remains one of the most intractable complications of glaucoma filtering surgery today and is predominantly characterized by raised intraocular pressure (IOP), a shallow anterior chamber, and the presence of a patent iridotomy. However, the pathogenesis of the disease is still unclear. It may be that the excessive adhesion of the lens, vitreous, and pars plana obstructs the entrance of the posterior aqueous humor to the anterior chamber, and the aqueous humor flows backward into the vitreous body to form a water sac. There are currently limited treatments available for malignant glaucoma [2]. Several surgical techniques have been reported, such as ND: YAG laser capsulotomy, zonulo-hyaloido-vitrectomy (ZHV), and modified partial pars plana vitrectomy combined with phacoemulsification [1,3,4]. These techniques are all related to the operation of the lens. However, no consensus has been reached regarding the optimal therapeutic strategy in the literature. Malignant glaucoma can develop in patients who have undergone trabeculectomy after chronic angle-closure glaucoma or other intraocular operations. After some patients were treated with medication, their aqueous humor circulation improved and the condition was relieved. However, in some cases, management with medication was ineffective and surgery was indicated [5]. Currently, surgical management of malignant glaucoma includes core vitrectomy [6], 25-gauge pars plana vitrectomy [7], and phacoemulsification combined with posterior capsulorrhexis and anterior vitrectomy [8]. The recurrence rate after surgery varies [6,9]. Since 2004, ciliary body incision combined with modified partial pars plana vitrectomy has been the primary choice of surgical treatment used for malignant glaucoma in our hospital. In our procedure, we mainly performed partial vitrectomy using the original incision channel, which caused limited disturbance to the internal tissue structure and fewer complications and retained the natural lens. We hope that our innovative surgical experience will help simplify the surgical procedure to achieve satisfactory therapeutic results.

Material and Methods

Subjects and clinical examinations

This was a retrospective case series. From May 2004 to March 2017, 13 cases (16 eyes) of malignant glaucoma were treated with surgical ophthalmic surgery in the Ninth People's Hospital of Wuxi City. This group comprised 5 men (6 eyes) and 8 women (10 eyes), with a mean age of 52.5±5.23years (range, 45–63 years). The diagnosis of malignant glaucoma was based on the presence of a shallow or flat anterior chamber, high IOP, and absence of choroidal effusion or suprachoroidal hemorrhage and findings from ultrasound biomicroscopy (UBM, Humphrey 840, Germany) which showed iris-corneal contact and anterior chamber flattening, forward displacement of the lens and iris bombe, and forward rotation of ciliary processes. All eyes included in the study underwent patent peripheral iridotomy except for 1 eye that underwent phacoemulsification and intraocular lens implantation. The clinical examination data are expressed in the following manner: axial length measured by type A ultrasound, best-corrected visual acuity (BCVA) represented by a logarithm of the minimal angle of resolution (LogMAR) score, anterior chamber depth measured by UBM, and IOP measured using a Goldman tonometer.

Surgical procedure

All operations were performed by a licensed physician.

1. Surgical methods: Routine medications, including mydriatic drugs, IOP-lowering drugs, and anti-inflammatory drugs, were administered preoperatively. A mixture of lidocaine 2% and bupivacaine 0.75% was prepared for retrobulbar anesthesia. For the eyes that had undergone trabeculectomy, the conjunctival and scleral flaps of the previous operation were opened; the deep sclera was cut 1.5 mm posteriorly (along with the total length of the first incision) on both sides of the original scleral bite incision and was removed. The deep sclera was separated from the ciliary body, and the separated ciliary body was cut off so that the scleral wall under the scleral flap was a "window"-like defect of approximately (2.5×2.5) mm^2. The exposed ciliary body and scleral bed were electrocoagulated; the ciliary body was removed after electrocoagulation, causing the ciliary ring to form a 2.5×2.5 mm^2 gap. Under the microscope, a 23-gauge vitrector was inserted from the incision from the outside to the interior of the anterior vitreous cavity partial vitrectomy. After the anterior chamber pressure decreased, corneal puncture was performed, and sodium hyaluronate was injected to inflate the anterior chamber and the detached corner. The scleral flap and the conjunctival flap were sutured closed. For patients who did not have a scleral flap, a 5×4 mm^2 scleral flap was routinely created; all other steps were the same as above. Tobramycin dexamethasone ointment was applied to the conjunctival sac of the eye, and the operation was completed. The schematic diagram of ciliary incision combined with modified partial pars plana vitrectomy is shown in Figure 1.
2. Postoperative treatment: After surgery, the patients were examined daily for IOP, and the slit lamp was used to inspect the patency of the cornea, anterior chamber, and surgical channel. For patients with severe postoperative inflammatory reaction, short-term oral steroids were administered for 5–7 days.

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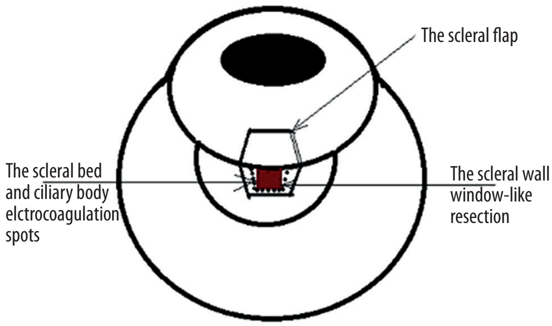

Figure 1. Schematic of ciliary incision combined with modified partial pars plana vitrectomy.

3. Postoperative follow-up: The subjects were followed for a mean of 33.1±10.6 months (range, 19–46 months). During the follow-up periods, the BCVA, IOP, cornea, anterior chamber depth, filtering blebs, lens, optic disc, and surgical complications were evaluated. Some patients also underwent visual field examination.

Data analysis

We performed statistical analysis using SPSS 17.0 statistical software (SPSS Inc., Chicago, IL, USA). The number of eyes in Table 1 comprises ordered classification level data, which were analyzed using the Mann-Whitney U test. One-way analysis of variance was used to compare both the preoperative and postoperative measurements of IOP and anterior chamber depth. P values less than 0.05 were considered statistically significant.

Results

The study comprised 8 cases (10 eyes) of acute angle-closure glaucoma after trabeculectomy, 1 case (1 eye) after onset of iris incision, 3 cases (4 eyes) after chronic trabecular glaucoma trabeculectomy, and 1 case (1 eye) after phacoemulsification and intraocular lens implantation. The shortest onset time from the primary disease to malignant glaucoma was 2 days and the longest was 7 years. Excluding the single case with a 7-year onset after trabeculectomy, the average time of onset was 6.4 days in the remaining 12 cases (15 eyes). The patient data measurements were calculated as follows: preoperative BCVA LogMAR score mean, 0.9±0.3 (range, 1.6–0.3); mean IOP, 41.30±6.41 mmHg (1 kPa=7.5 mmHg; range, 29.32–65.21 mmHg); average axial length, 21.45±0.88 mm (range, 19.43–23.12 mm); average depth of the central anterior chamber, 0.9±0.3 mm (range, 0.4–1.5 mm); average follow-up time, 33.1±10.6 months (range, 19–46 months). The patient characteristics are listed in Table 2.

Table 1. Number of eyes with corresponding changes in best-corrected visual acuity (BCVA) before and after surgery.

BCVA (LogMAR)	Pre-operation	1 year after surgery
<0.4	0	9
0.4	1	2
0.5~1.0	4	3
>1.0	11	2

Z=–3.853, P=0.000.

Table 2. Patient characteristics.

	Mean (SD)	Range
Age	52.5±5.23	45~63
Axial length	21.45±0.88	19.43~23.12
MG duration	5.5±2.5	3~9
CCT	533±26	484~575
Follow-up time	33.1±10.6	19~46

Of the 13 patients we observed (16 eyes), preoperative treatments included topical mydriatics, topical anti-glaucoma drugs, oral carbonic anhydrase inhibitors, and the systemic use of mannitol. In some patients, these treatments temporarily deepened the anterior chamber depth and led to IOP reduction, but the ciliary blockade was not resolved.

After our surgical intervention, a postoperative anterior chamber gradually formed; one year after surgery, the BCVA was improved in 11 eyes, with a BCVA (Log MAR) score of 0.1. However, 4 eyes remained unchanged, and visual acuity decreased in 1 eye. The number of eyes with improved visual acuity 1 year after surgery was significantly different from the preoperative difference (Z=–3.853, P=0.000). After our surgical intervention, the anterior chamber depth ranged from a mean of 0.9±0.3 mm preoperatively to a mean of 2.6±0.2 mm 1 week postoperatively (P<0.001); the difference remained statistically significant at 1 year postoperatively (F=154.792, P^a<0.001; Figure2). The preoperative IOP decreased from a mean of 41.3±6.4 mmHg to a mean of 10.4±3.9 mmHg on the first postoperative day, and the difference was found to be significant (P<0.001). The difference was statistically significant at 1 year postoperatively (F=48.650, P^b<0.001; Figure3). The data regarding the number of eyes with changes in the values of BCVA, anterior chamber depth, and IOP are listed in Tables 1 and 3.

In the follow-up observation, a shallow anterior chamber had formed in 1 eye, and the shallow anterior chamber disappeared within 1 week after the operation. In 1 eye, a traumatic cataract was caused by lens injury. In the 7th month after the

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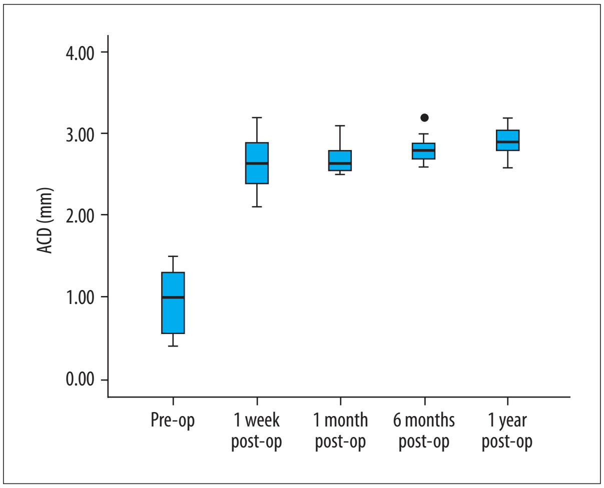

Figure 2. Anterior chamber depth (ACD; median, range, and outliers) measured during each follow-up visit.

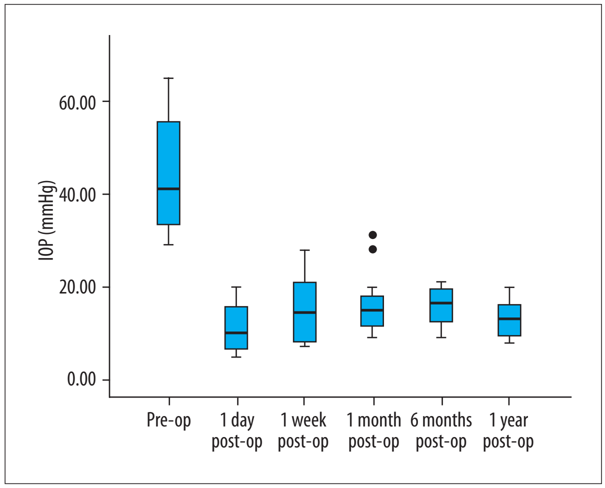

Figure 3. Intraocular pressure (IOP; median, range, and outliers) measured during each follow-up visit.

Table 3. Analysis of changes in intraocular pressure and anterior chamber depth before and after surgery.

	Anterior chamber depth (mm)			Intraocular pressure (mm Hg)		
	Mean (SD)	Range	P value[a]	Mean (SD)	Range	P value[b]
Pre-op	0.9±0.3	0.4~1.5		41.3±6.4	29~65	
1st day	–	–	–	10.4±3.9	5~22	<0.001
1st week	2.6±0.2	2.1~3.2	<0.001	15.3±6.3	7~28	<0.001
1st month	2.7±0.1	2.5~3.1	<0.001	16.3±6.2	9~31	<0.001
6th month	2.8±0.1	2.6~3.2	<0.001	15.4±3.1	9~21	<0.001
1 year	2.9±0.2	2.6~3.2	<0.001	14.2±3.3	8~20	<0.001

"–", data not available(UBM was not performedon the 1st day after surgery). P-values are based on one-way ANOVA; F=154.792, P[a]<0.001; F=48.650; P[b]<0.001.

operation, phacoemulsification removal and intraocular lens implantation were performed. Postoperatively, IOP was stable at between 13 and 16 mmHg, and the BCVA (Log MAR) score was 0.3. Choroidal detachment occurred in another eye and the patient recovered after 35 days with no special treatment. The anterior chamber cellulose exuded in 1 eye and resolved within 1 week. In 2 cases, the anterior chamber disappeared again on the 4th and 11th day after surgery, respectively, and IOP increased to more than 38 mmHg. The second vitrectomy was performed according to the surgical procedure described above. The postoperative anterior chamber depth returned to 2.30–2.88 mm and IOP was ≤19 mmHg. In this study, patients who needed a second intervention were excluded and the success rate was 14/16 (87.5%).

Discussion

The pathogenesis of malignant glaucoma is not yet fully understood, but it is directly related to abnormal anatomical development in the anterior segment of the eye [10]. Research data show that malignant glaucoma is associated with a short axial length, a shallow anterior chamber, hypertrophic pronation of the ciliary process, a relatively large lens size, a small equator of the ciliary process-lens, and abnormal attachment of the vitreous base and ciliary body [11,12]. We measured the mean axial length of the patients in this study at 21.45±0.88 mm, which was similar to that found by He et al. (21.3±0.8 mm) [4] and Wang et al. (21.56±0.84 mm) [13]. Thus, a short axial length may be a common feature of patients with malignant glaucoma. At present, the treatment of malignant glaucoma is the most urgent research task. The key to the treatment of malignant glaucoma is to correct the misdirected flow of the aqueous humor and restore normal aqueous humor circulation.

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The treatment of malignant glaucoma includes drug therapy and surgical intervention. Disease management with medication commonly focuses on the release of ciliary muscle spasm, inhibition of aqueous humor production, the introduction of systemic osmotic agents used to decrease vitreous volume, and the reduction of inflammation; when patients do not respond well to medication, surgery is necessary, but determining the optimal surgical management can be difficult. At present, one surgical treatment option involves the removal of the lens combined with anterior vitrectomy [4,8,14]. When patients with malignant glaucoma are relatively young, the lens is still transparent and it has a certain degree of accommodation. After surgery, the patient loses this physiological refraction and accommodation. Lens removal combined with the anterior vitrectomy procedure is also complex and requires relatively high technical skill and special equipment. Additionally, this type of treatment is associated with large disturbances in the tissues of the eye, a greater postoperative inflammatory response, and a less than ideal prognosis. Little et al. and Halkias et al. used Nd: YAG laser capsulotomy and hyaloidotomy to reconstruct areas that control the pressure in the eye, which included reducing the ciliary block and reversing the misdirection of aqueous humor; this also prevented acute surgical intervention [15,16]. For cases in which drug therapy failed to effectively control IOP in malignant glaucoma, Herschler et al. and Stumpf et al. used the technique of transscleral cyclodiode laser ciliary body ablation to reduce the production of aqueous humor and reversed the posterior secretion of aqueous humor [1,17]. However, this technique is not ideal because it is a destructive surgical procedure and is accompanied by a high chance of recurrence [18]. ZHV can be selected as an alternative surgical approach for pseudophakic malignant glaucoma in patients who failed medical or laser treatment. The 2 surgical series that treated malignant glaucoma using ZHV had a near 100% success rate at <1-year follow-up [19,20]. However, in the 4-year observation period of the ZHV surgical follow-up case series, the recurrence rate was 66%, which may have been due to the anterior movement of the vitreous and the obstruction of the channel caused by zonulectomy-iridectomy [3]. For patients with pseudophakic malignant glaucoma, recurrence of malignant glaucoma after ZHV occurred in 40% of cases at a mean follow-up of 50.2±27.2 months. Bitrian et al. found that the iridectomy zonulectomy/vitrectomy technique treatment's success rate was 100% at a mean follow-up of 7.6 months [19]. The success rate of that operation seems to be higher than that of ours. However, the recurrence rate of our operation was 2/16 (12.5%) at a mean follow-up of 33.1+10.6 months.

In our study, we carried out ciliary ring incision combined with modified partial pars plana vitrectomy surgery from the outside to the inside using clear tissue exposure and the formation of a clear and reliable vitrectomy channel. This was a relatively simple and safe surgical operation, which caused little disturbance to the intraocular tissue structure and resulted in fewer complications when compared to other surgical methods. This technique was also associated with only mild surgical inflammation, rapid recovery, and a good prognosis. Another major advantage in using this approach is that retention of the lens preserves refraction and partial accommodation; moreover, it avoids further destruction of the anterior segment of the eye and aids in the restoration of the anatomy and function of the eye. Compared to current surgical options, such as pars plana vitrectomy with or without lens surgery, vitreous puncture with aspiration, ZHV, vitrectomy-phacoemulsification-vitrectomy, and pars plana tube insertion with vitrectomy [3,8,14,18,21–22], with our technique, we have a wider choice of surgical options, especially for younger patients with a transparent lens. In addition, during the operation, we could see the water sac under direct vision, and the vitreous cavity was less disturbed when the vitreous was resected. Among the patients who participated in our study, the BCVA of 11 patients had improved at 1 year after surgery compared with that before surgery. A study by Wu et al. showed similar results, indicating that there is good prognosis for vision in patients with malignant glaucoma who receive appropriate and timely intervention [23].

The purpose of our operation was to restore normal circulation to the misdirection of the aqueous humor (water sacs→ vitreous cavity→ crystal equator→ posterior chamber→ peripheral iris incision (or the pupil)→ anterior chamber→ subconjunctival or directly under the scleral flap→ subconjunctival). For 2 cases requiring repeated vitrectomy, we believe that the features of the eyeball were unrelated, and there may be 2 reasons for this. On the one hand, the water sacs in the vitreous cavity were not resected. On the other hand, the normal aqueous humor circulation channel was not completely established. Even though phacoemulsification of the lens may have prevented initial failure, we were ultimately able to preserve the natural lens. In our study, 1 patient had a traumatic cataract, which was caused by the surgical operation, which alerted us to remain vigilant against this potential complication in the future, which may be another limitation of leaving the natural lens. In 1 case, choroid detachment occurred, which was possibly caused by leakage at the incision or inflammatory exudation because of postoperative low intraocular pressure. In addition, in 1 case, exudation of the anterior chamber cellulose occurred, mainly because of uveal inflammation caused by the surgery. For severe postoperative inflammatory response, such as a fog edema opacity of the cornea, anterior chamber exudate, and heavy conjunctival congestion edema, which is not a response specific to this technique, treatment with 0.5 mg per kilogram of body weight of oral prednisone should be administered once per day for 5–7 days. Most patients only use local hormone eye drops. Naturally, after routine surgery,

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dexamethasone 2 mg should be administered by subconjunctival injection, which can reduce inflammation [3, 4]; however, this was not performed after our operations.

Regarding our modified surgery, we need to pay attention to the following issues: (1) Drug therapy for malignant glaucoma is only a temporary treatment strategy that does not correct the fundamental problem, and, therefore surgical intervention should be performed early (2). The surgeon should use caution when cutting the vitreous body. The negative pressure should not be too low, and the cutting speed should be slow. At the same time, a viscoelastic agent should be injected into the anterior chamber to maintain IOP, restore the anterior chamber depth, and open the anterior chamber angle. The surgical procedure is performed under direct vision with the microscope. The operator must not mistakenly damage the lens. The extent of vitrectomy is not required to be too large as long as some of the vitreous front membrane and the anterior cortex are excised, but it is necessary to reach the water sac (3). When the ciliary body is excised, the corresponding sclera of the flat surface and both wound surfaces should be closed using electrocoagulation to prevent choroidal detachment after surgery.

Conclusions

Ciliary ring incision combined with modified partial pars plana vitrectomy, which we carried out for the treatment of malignant glaucoma, may simplify the operation procedure. Not only does it provide clear and reliable intraoperative vitrectomy channels, it is also associated with less disturbance of intraocular tissue structure and fewer complications. Perhaps the greatest advantage of using this technique is preservation of the lens and retention of refractive and partial accommodation. Additionally, as it avoids further damage to the anterior segment of the anatomy, it contributes to the restoration of the anatomy and function of the eye. Our innovative surgical procedure is more suitable for younger patients, especially those who wish to preserve the natural lens. As a limitation of our technique, we did not treat patients with cataract with turbid or swollen lenses, which may result in traumatic cataract. We need to be cautious in avoiding damaging the lens and minimizing intraocular tissue disturbance to reduce postoperative inflammatory reactions. Naturally, larger sample sizes and longer observation periods are needed to demonstrate the effectiveness and safety of this surgical procedure.

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