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Reevaluation of Full-Width Tenotomy of Four Rectus Muscles Combined with Transscleral Pars Plana Cyclocryoapplication for Intractable Neovascular Glaucoma

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We reevaluated full-width tenotomy of 4 rectus muscles combined with transcleral pars plana cyclocryoapplication for intractable neovascular glaucoma. Fifteen patients (15 eyes) with advanced, uncontrollable neovascular glaucoma resulting from various causes were treated with the new surgical procedures. The visual acuity ranged from no light perception to hand motion. As the surgery was intended to disrupt all the anterior ciliary arteries in the rectus muscles, we added the cyclocryoapplication to the site of insertion before resuturing of the severed muscles, with the aim of interrupting the recanalization of the fully cut ciliary vessels. The patients were followed up for 6 to 78 months, average 55.7 months. At the end of follow-up, all 15 eyes had no light perception. The intraocular pressure level decreased from the preoperative level of 53.7 ± 13.4 mmHg (mean ± SD) to 13.0 ± 5.3 mmHg without additional medical therapy. The decrease was significant ($P < 0.0001$). The intraocular pressure remained below 10 mmHg in 5 eyes, one of which became phthisic. Prominent rubeosis iridis regressed or appeared to regress in the 15 eyes. All patients felt comfortable. No patients complained of ocular pain, headache or vomiting after surgery. The findings reconfirm that the current surgical procedure is beneficial and effective in the management of uncontrollable neovascular glaucoma with extremely poor vision.

Key words: anterior ciliary arteries; 4 rectus muscles; full-width tenotomy; neovascular glaucoma; transscleral pars plana cyclocryoapplication

Medication and surgical treatment for eyes suffering from rubeosis iridis and neovascular glaucoma have always been problematic. Topical cycloplegics and corticosteroids relieve pain, but do not control the glaucoma (Drews, 1974; Kanski and McAllister, 1989). Carbonic anhydrase inhibitors decrease intraocular pressure, but rarely provide satisfactory control. Regarding surgical procedures for neovascular glaucoma, angle vessel or panretinal photocoagulation appears to be beneficial before fibrovascular tissue has significantly closed the angle. However, once neovascular glaucoma has been established, these therapies are usually ineffective (Wand et al., 1978; Fukuda et al., 1980; Suguro et al., 1987). Modified conventional filtration surgery and artificial filtering shunts are considered by some (Sinclair et al., 1982; Schocket et al., 1985; Kanski and McAllister, 1989) to be preferential treatments for eyes with rubeosis iridis and neovascular glaucoma. Cyclodestructive procedures including cyclocryotherapy, transscleral neodymium: YAG (yttrium aluminum garnet) laser cycloablation and cyclophotocoagulation ab externo are usually indicated when all hope of salvaging useful vision is lost, but rarely provide satisfactory control (Krupin et al., 1978; Wesley and Kielar, 1980; Kanski and McAllister, 1989; Hamano et al., 1992; Inaba et al., 1994).

Table 1. Subject patients with advanced, uncontrollable neovascular glaucoma

Patient No.	Age (year)	Sex	Side (eye No.)	Cause
1 E. M.	72	M	L (1)	Proliferative diabetic retinopathy
2 K. A.	71	F	R (2)	Unknown
3 Y. E.	61	F	L (3)	Unknown
4 F. S.	64	M	R (4)	Proliferative diabetic retinopathy
5 M. T.	85	F	R (5)	Unknown
6 Y. K.	67	F	L (6)	Central retinal vein occlusion
7 Y. T.	81	M	L (7)	Unknown
8 K. I.	75	M	L (8)	Unknown
9 T. H.	68	M	L (9)	Unknown
10 K. T.	76	M	R (10)	Senile disciform macular degeneration
11 N. T.	61	F	L (11)	Unknown
12 N. S.	52	M	R (12)	Unknown
13 M. F.	59	F	L (13)	Proliferative diabetic retinopathy
14 M. E.	70	F	R (14)	Proliferative diabetic retinopathy
15 H. K.	62	M	L (15)	Central retinal vein occlusion
Mean ± SD	68.3 ± 8.8			

F, female; L, left eye; M, male; R, right eye.

Since 1985, after observing and considering the mechanism of the anterior segment ischemia associated with strabismus surgery (Girard and Beltranena, 1960; McKeown et al., 1989; Kanski and McAllister, 1989), we have carried out a new surgical treatment, consisting of full-width tenotomy of 4 rectus muscles combined with transscleral pars plana cyclocryoapplication, for patients with advanced, uncontrollable neovascular glaucoma and extremely poor vision, with beneficial and effective results (Tamai et al., 1988, 1990, 1992; Hosogi et al., 1990). We reevaluate herein the favorable results achieved by these techniques in other patients with intractable neovascular glaucoma.

Table 2. Visual acuity of 15 eyes before and after surgery

Eye No.	Visual acuity		Months followed
	Before	After	
1	No light perception	No light perception	78
2	No light perception	No light perception	78
3	No light perception	No light perception	76
4	No light perception	No light perception	76
5	No light perception	No light perception	72
6	No light perception	No light perception	66
7	No light perception	No light perception	62
8	No light perception	No light perception	61
9	No light perception	No light perception	61
10	No light perception	No light perception	60
11	No light perception	No light perception	56
12	No light perception	No light perception	43
13	No light perception	No light perception	31
14	Hand motion	No light perception	10
15	Light perception	No light perception	6
Mean			55.7

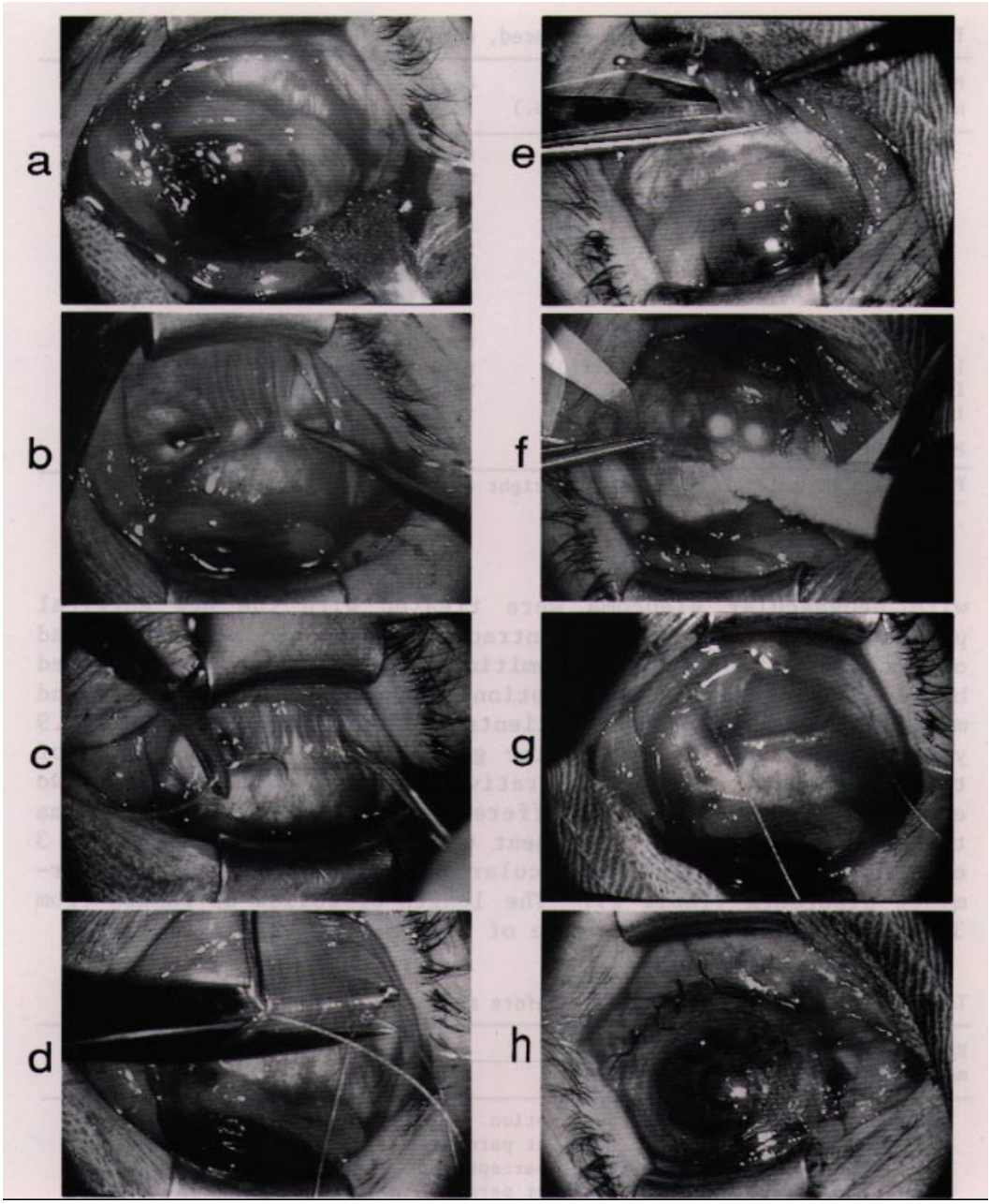

Fig. 1. View of the operation. A 360˚ peritomy of the conjunctiva is first made 2 mm posterior and parallel to the limbus (**a**). Then, the superior rectus muscle is hooked using a muscle hook (**b**) and a 5-0 catgut mattress is placed on both sides at the end of the superior rectus tendon (**c**). Under these conditions, a full-width, superior rectus tenotomy is performed (**d, e**). The other 3 rectus muscles are tenotomized one by one in the same way. Transscleral cyclocryoapplication is performed at each insertion by using a retinal probe of the Amoils Cryo Systems: 20 to 30 s, –65˚C, a total of 15 spots with 3 rows of 5 applications (**f**). Then, the severed muscles are individually resutured at the insertion points (**g**). Finally the conjunctiva is interruptedly closed with 8-0 virgin silk (**h**).

Table 3. Intraocular pressure of 15 eyes before and after surgery

Eye No.	Intraocular pressure (mmHg)			Paired *t*-test	Months followed	Remarks
	Before	After*	Difference			
1	44	10	–34		78	
2	56	16	–40		78	
3	40	8	–32		76	Phthisis bulbi**
4	38	15	–23		76	
5	59	8	–51		72	
6	45	16	–29		66	
7	40	26	–14		62	
8	46	13	–33		61	
9	46	15	–33		61	
10	72	18	–54		60	
11	50	16	–34		56	
12	76	12	–64		43	
13	55	8	–47		31	
14	80	6	–74		10	
15	58	8	–50		6	
Mean ± SD	53.7 ± 13.4	13.0 ± 5.3	–40.8 ± 15.8	$P < 0.0001$	55.7	

*No subsequent medical treatment of neovascular glaucoma was required.
**20.0% of 5 hypotonic eyes below 10 mmHg and 6.7% of all 15 eyes.

Subjects and Methods

Between July 1989 and June 1995, 15 patients (15 eyes) with neovascular glaucoma were treated with the new surgical procedures for uncontrolled intraocular pressure and associated ocular pain, headache and vomiting, with the consent of the subject patients. Intraocular pressure was measured with a Goldmann application tonometer attached to a slitlamp biomicroscope (Carl Zeiss Co., Ltd., Japan, Tokyo, Japan). The operated eyes ranged between having no light perception and the ability to detect hand motion. The age of the patients at surgery was 68.3 ± 8.8 years (mean ± SD). Neovascular glaucoma occurred in 4 eyes of the 4 patients with proliferative diabetic retinopathy, in 2 eyes of the 2 patients with central retinal vein occlusion and in 1 eye of the 1 patient with senile disciform macular degeneration. The other 8 eyes of the remaining 8 patients had undetermined disorders (Table 1). The length of follow-up ranged from 6 to 78 months, average 55.7 months (Table 2).

Details of our surgical procedures have been fully described elsewhere (Tamai et al., 1988, 1990, 1992; Hosogi et al., 1990), and only the main points will be outlined below, as demonstrated in Fig. 1.

We performed full-width tenotomy on the 4 rectus muscles to disrupt all the anterior ciliary arteries in the muscles on 15 eyes in the 15 patients under local anesthesia. The tenotomy was done by instillation of 0.4% oxybuprocaine hydrochloride and by retrobulbar injection of 2% xylocaine (Figs. 1d and 1e). Although the severed muscles were resutured at the insertion points, transscleral cyclocryoapplication was added at each insertion before resuturing, with the aim of interrupting the recanalization of the fully cut ciliary vessels. A single-freeze-thaw technique (lasting 20 to 30 s) was used at -65˚C with a retinal probe (2.5 mm diameter) from the Amoils Cryo Systems (Konan Keeler Ltd., Osaka, Japan). The 15 eyes received 15 applications at each insertion (a total of 15 spots with 3 rows of 5 applications) (Fig. 1f). All eyes received topical antibiotics and corticosteroids after the operation for at least 1 week. No subsequent antiglaucoma medication was applied.

Table 4. Rubeosis iridis of 15 eyes before and after surgery

Eye No.	Rubeosis iridis Before	Rubeosis iridis After	Months followed
1	Stage IV*	Regressed	78
2	Stage IV	Regressed	78
3	Stage IV	Regressed	76
4	Stage IV	Appeared to regress	76
5	Stage IV	Regressed	72
6	Stage IV	Regressed	66
7	Stage IV	Appeared to regress	62
8	Stage IV	Appeared to regress	61
9	Stage IV	Appeared to regress	61
10	Stage IV	Appeared to regress	60
11	Stage IV	Appeared to regress	56
12	Stage IV	Regressed	43
13	Stage IV	Appeared to regress	31
14	Stage IV	Appeared to regress	10
15	Stage IV	Regressed	6
Mean			55.7

*Stage IV in the classification of Fukuda and others (1980).

Results

At the end of follow-up, 13 eyes having no light perception before surgery (86.7% of the 15 eyes treated) remained unchanged after surgery. No light perception was observed postoperatively in 1 eye having hand motion (6.7%) and in 1 eye having light perception before surgery (6.7%), indicating that all 15 eyes had no light perception after surgery (Table 2).

The intraocular pressure level decreased from the preoperative level of 53.7 ± 13.4 mmHg (mean ± SD) to 13.0 ± 5.3 mmHg without any subsequent medical treatment. The decrease was statistically highly significant by the paired *t*-test ($P < 0.0001$). The intraocular pressure remained below 10 mmHg in 5 eyes (33.3% of the 15 eyes), one of which became phthisic (20.0% of the 5 hypotonic eyes and 6.7% of the 15 eyes) (Table 3).

Prominent rubeosis iridis with secondary angle-closure glaucoma, Stage IV in the classification of Fukuda and others (1980), was observed in all 15 eyes before surgery through slit-lamp biomicroscopic and gonioscopic examinations. Final examination revealed that the neovascularization of the iris in Stage IV had regressed in 7 eyes (46.7% of the 15 eyes) and appeared to regress in 8 eyes (53.3%) (Table 4).

Figure 2 presents the preoperative situation of the left eye in Patient 3. Prominent dilated rubeosis iridis is visible. Figure 3 presents the postoperative situation of the left eye in the patient. This photograph was taken 1 month after surgery. The remarkable regression of the rubeosis iridis is obvious.

All patients were comfortable. No patients complained of ocular pain, headache or vomiting after surgery, although the grade of severity had been different for each patient before surgery (Table 5).

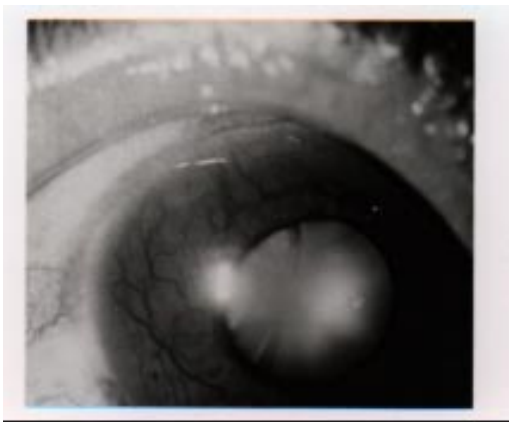

Fig. 2. Preoperative condition of Patient 3 (left eye).

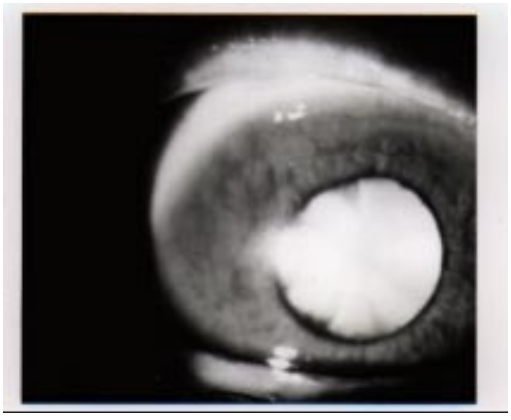

Fig. 3. Postoperative condition of Patient 3 (left eye), 1 month after surgery.

Table 5. Subjective complaints of 15 patients before and afte surgery

Patient No.	Ocular pain		Headache		Vomiting		Months followed
	Before	After	Before	After	Before	After	
1 E. M.	++	–	++	–	+	–	78
2 K. A.	++	–	++	–	+	–	78
3 Y. E.	++	–	++	–	±	–	76
4 F. S.	+	–	+	–	±	–	76
5 M. T.	++	–	++	–	++	–	72
6 Y. K.	++	–	++	–	+	–	66
7 Y. T.	++	–	++	–	+	–	62
8 K. I.	++	–	++	–	+	–	61
9 T. H.	++	–	++	–	+	–	61
10 K. T.	+++	–	+++	–	++	–	60
11 N. T.	++	–	++	–	++	–	56
12 N. S.	++	–	++	–	++	–	43
13 M. F.	++	–	++	–	+	–	31
14 M. E.	++	–	++	–	++	–	10
15 H. K.	++	–	++	–	++	–	6
Mean							55.7

Severity indexes (+++, ++, +, ±): no complaint is indicated as –.

Discussion

The posterior ciliary arteries in itself produce no important changes in the anterior segment (Virdi and Hayreh, 1987) and the majority of blood flow to the anterior segment is carried by the anterior ciliary arteries (Wilcox et al., 1980). Therefore, interruption of the anterior ciliary arteries during a rectus muscle tenotomy is generally accepted as the cause of the anterior segment ischemia which follows strabismus surgery (Girard and Beltranena, 1960; Wilcox et al., 1980; Vird and Hayreh, 1987; McKeown et al., 1989). The pathogenesis of anterior segment ischemia is not completely understood, but is presumably related to some perturbation of the blood supply to the anterior segment, resulting in iridocyclodestruction (McKeown et al., 1989). The anterior segment ischemia associated with strabismus surgery may decrease uveal blood flow and obliterate capillary circulation at the iris and ciliary processes, producing a decrease in active and passive aqueous secretions (McKeown et al., 1989; Kanski and McAllister, 1989).

Since 1985, after observing and considering the mechanism of the anterior segment ischemia (Girard and Beltranena, 1960; McKeown et al., 1989; Kanski and McAllister, 1989), we have carried out the new surgical treatment in patients with advanced, refractory neovascular glaucoma resulting from various causes and only allowing vision to range from the inability to perceive light to the ability to perceive hand motion (Tamai et al., 1988, 1990, 1992; Hosogi et al., 1990), as mentioned above.

In our present study, 15 patients (15 eyes) with advanced, intractable neovascular glaucoma had no light perception in 13 eyes and hand motion in the other 2 eyes before surgery. In glaucoma patients with no useful vision, the control of associated ocular pain, headache or vomiting is usually more important than the control of elevated intraocular pressure (Tamai et al., 1988, 1990). Our new surgical technique provided relief from the subjective complaints, especially persistent ocular pain without enucleation or retrobulbar alcohol injection (Tamai et al., 1988, 1990, 1992; Kanski and McAllister, 1989; Hosogi et al., 1990). This result suggests that sensory nerves or pain receptors in the eyeball are likely to degenerate with the anterior segment ischemia derived from the surgery (Awaya et al., 1989). In the present study, no patients complained of ocular pain, headache or

even vomiting either after surgery. All subject patients felt comfortable after surgery.

The preoperative intraocular pressure (53.7 ± 13.4 mmHg) significantly decreased ($P < 0.0001$) postoperatively to 13.0 ± 5.3 mmHg without any subsequent medical treatment, and prominent rubeosis iridis regressed or appeared to regress postoperatively in the 15 eyes in the present study.

Although just 1 eye became phthisic at the end of follow-up in this survey, the relatively high incidence of late serious complications, such as hypotony defined as less than 10 mmHg and phthisis bulbi, may be caused by excessive destruction of the ciliary body by these cyclodestructive procedures (Tamai et al., 1988, 1990, 1992; Hosogi et al., 1990). The combined transscleral pars plana cyclocryoapplication might influence the ciliary processes and the peripheral retina (Kurpin et al., 1978; Wesley and Kieler, 1980; Tamai et al., 1988, 1990, 1992; Kanski and McAllister, 1989). Therefore, we believe that there is a need to develop other modified forms of our procedures for eyes with vision potential, i.e., tenotomy of 3 or 4 rectus muscles without cyclocryoapplication and simultaneous recession (Awaya et al., 1989) or advancement of the severed muscles (Tamai et al., 1992).

In conclusion, various types of operation for neovascular glaucoma rarely provide satisfactory control (Kurpin et al., 1978; Wand et al., 1978; Fukuda et al., 1980; Wesley and Kieler, 1980; Sinclair et al., 1982; Schocket et al., 1985; Kanski and McAllister, 1989; Hamano et al., 1992; Inaba et al., 1994), but the results obtained in the present study reconfirm the previous evaluation that the current surgical procedure is beneficial and effective in the management of uncontrollable neovascular glaucoma with extremely poor vision (Tamai et al., 1988, 1990, 1992; Hosogi et al., 1990).

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