Discussion

Our results showed that the amplitudes of the b-wave of the mixed rod-cone ERGs and the PhNR of the photopic ERG in an eye with a CRAO were significantly smaller than that of the healthy fellow eye. Furthermore, the a/f ratio of the PhNR, which reflects the severity of the RGC damage, was positively correlated with the inner-layer ratio, which may reflect the thinning of the inner layer including the NFL layer. Schmidt et al. have reported [9, 12] that the extent of macular edema determined by OCT at the acute phase (24.7±5.0 hours; mean±SD) varied widely, and did not affect the prognosis in terms of visual acuity in eyes with a CRAO. Leung et al. have illustrated the structural damages in terms of reduction in the macular and peripapillary NFL thickness measured at least 1 year after onset of CRAO and their correlation with the visual field defects [10]. In agreement, our results showed that the thinning of the inner retina is closely correlated with the degree of ERGs changes. However, the changes in the thickness of the retina at the acute phase could not be used for the prognosis of the eyes following a CRAO. Further investigations are needed to determine a way of assessing the extent of irreversible RGC changes at the acute phase of the disease.

Our study has several limitations, e.g., small case numbers, inability to measure the thickness of the NFL accurately, and different treatments for the CRAO. These limitations were due to the retrospective nature of the study. No comparison was available between patients with embolic cause and without embolic cause and between patients with only central retinal artery occlusion and with additional choroidal ischemia. These comparisons in a larger series would be of interest. In addition, the PhNR, which reflects the response of the entire retina, was used, and only an approximate evaluation on macular function could be made. Nevertheless, the PhNR has been shown to be sensitive enough to detect localized retinal alterations caused by indocyanine green-assisted ILM peeling during macular hole surgery [13]. It would be interesting to study the relationship of retinal thickness and retinal function in corresponding areas by multifocal ERGs.

Thus our results should be cautiously interpreted, but this study still provides useful clinical evidence that the functional evaluation by the ERGs and morphological evaluation by OCT are closely correlated, and each would be a good indicator of the severity of retinal ischemia.

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Contributions of authors: conception and design of the study (KS, KY, CSM); conduct of the study (KS, KY, CSM, KK); acquisition and analysis of the data (KS, KY, CSM, KK); writing the article; (KS, CSM); critical revision of the article (KY, CSM, KN); literature search (KS, CSM); statistical performance (KS); and supervision (KN).

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Letter to the Editor

Retinal circulatory disturbances following intracameral injection of bevacizumab for neovascular glaucoma

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Editor,

Bevacizumab (Avastin®; Genentech Inc., San Francisco, California, USA), an antivascular endothelial growth factor antibody, has been used widely to treat ocular neovascularizations (Grisanti et al. 2006; Silva Paula et al. 2006; Pedersen et al. 2007). However, the indications and optimal dosages have not been determined.

A 60-year-old woman was referred for treatment of proliferative diabetic retinopathy in her right eye, which had undergone vitrectomy, panretinal photocoagulation and cataract surgery with intraocular lens implantation. Her visual acuity was 20/200 and intraocular pressure (IOP) was 20 mmHg. Slit-lamp examination revealed iris and angle neovascularization. Ophthalmoscopy showed a whitening of the retinal arteries, blot haemorrhages and neovascularization on the disc (Fig. 1A). Fluorescein angiography showed diffuse leakage but no obvious occlusion of the retinal vessels (Fig. 1B). Additional retinal photocoagulation failed to control the neovascularization, and IOP increased to 50 mmHg. Corneal oedema prevented further laser application.

After a lengthy discussion of the potential risks and benefits of bevacizumab, the patient signed a consent form for an off-label intracameral injection of bevacizumab.

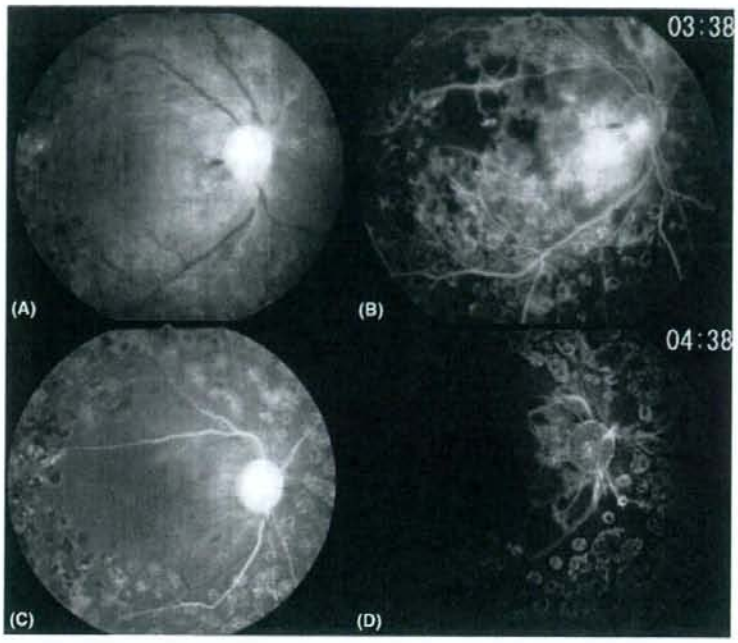

Fig. 1. Fundus photographs and fluorescein angiograms of a patient with neovascular glaucoma before and after intracameral bevacizumab. (A) Fundus photograph of the right eye showing a whitening of the retinal arteries in all quadrants, blot haemorrhages and neovascularization on the disc. (B) Fluorescein angiogram showing diffuse leakage in the posterior pole but no obvious occlusion of the retinal vasculatures. (C) Fundus photograph of the right eye 4 weeks after an intracameral injection of bevacizumab showing extensive attenuation of the retinal veins and whitening of the retinal arteries. (D) Fluorescein angiogram of the right eye taken 4 weeks after an intracameral injection of bevacizumab showing no filling of the retinal vessels except just around the optic disc.

One week after 1.25 mg of bevacizumab was injected, the iris and angle neovascularization had regressed completely. IOP was 20 mmHg. However, 4 weeks later, ophthalmoscopy showed extensive attenuation and occlusion of both arteries and veins (Fig. 1C,D). Although her visual acuity was maintained at 20/200, the circulatory alterations were unchanged after 1 year.

Such retinal vascular occlusions following bevacizumab have not been reported, even in eyes with ocular ischaemic syndrome (Amselem et al. 2007). Ultrastructural changes of the choriocapillaris have been reported after an intravitreal bevacizumab injection in monkeys (Peters et al. 2007). Although the ocular circulatory changes may be related to the patient's prior systemic and ocular conditions, bevacizumab might be the causative factor. Despite the rapid clearance of bevacizumab, a relatively high dose of bevacizumab might act on the posterior retina in a vitrectomized eye.

Our findings indicate that patients should be monitored carefully after intraocular bevacizumab injection for vascular complications.

Acknowledgements

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PHOTOGRAPHIC ESSAY

Severe acute ocular ischemia associated with spontaneous internal carotid artery dissection

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Abstract A healthy 40-year-old man developed unilateral ocular ischemic syndrome as the only manifestation of a spontaneous internal carotid artery dissection.

Keywords Ocular ischemic syndrome · Central retinal artery occlusion · Ophthalmic artery occlusion · Internal carotid artery dissection

Case report

A healthy 40-year-old man complained of a sudden decrease of vision in his right eye. His visual acuity was light perception OD and 1.2 OS. Ophthalmoscopy revealed a swelling of the optic disc and severe retinal edema in the posterior and peripheral retina (Fig. 1). Fluorescein angiography (FA) showed a marked delay in the arm-to-retina time and a delay in the choroidal flush (Fig. 1). Indocyanine angiography (IA) showed patchy hypofluorescent areas corresponding to the filling defects observed by FA. The *a*- and *b*-waves of the electroretinograms were decreased in the right eye, suggesting that the outer retina was also affected (Fig. 1).

A complete obstruction of right internal carotid artery (ICA) was observed by cervical magnetic resonance angiography (Fig. 2), and cerebral angiography revealed a complete obstruction and swelling at the beginning of the right ICA. However, the right cerebral artery was filled through shunt vessels from the left ICA. A diagnosis of a spontaneous ICA dissection was made, but intensive treatment including intravenous injection of urokinase, anterior chamber paracentesis, and oral acetazolamide and nitroglycerin failed to improve the vision.

Comments

Biousse et al. [1] reported that about one-third of patients with a spontaneous dissection of the ICA had a stroke within the first 2 weeks, and this was followed by ocular symptoms. Thus, a rapid evaluation of the cerebral circulation ipsilateral to an ICA dissection and proper treatment are highly important.

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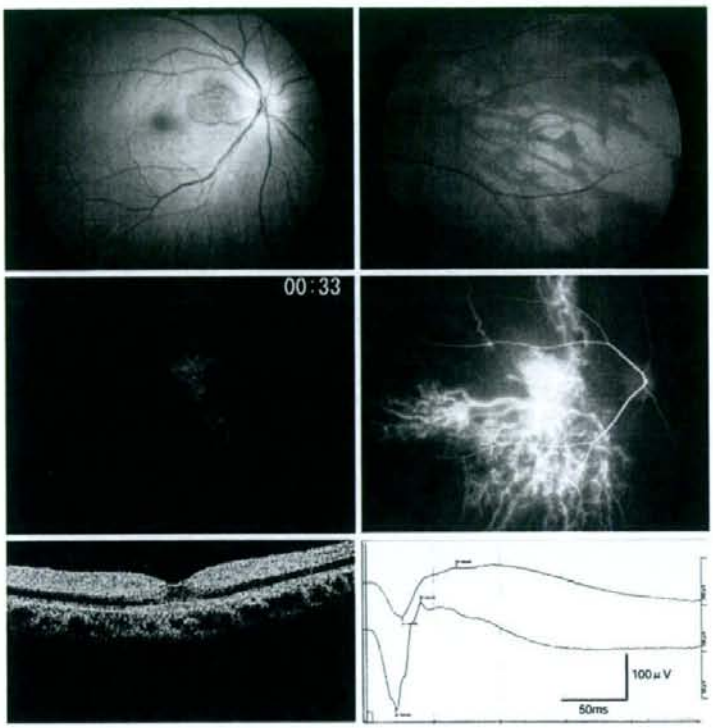

Fig. 1 Ocular findings in the right eye of a patient with a dissection of the right internal carotid artery. *Top left* Fundus photograph showing swelling of optic disc and diffuse retinal edema with a cherry-red spot. *Top right* An irregular retinal whitening of the peripheral retina is observed. *Middle left* Fluorescein fundus angiogram in the early phase showing a filling delay in retinal as well as choroidal circulations. A patchy defect of the choroidal filling is also seen. *Middle right* Indocyanine green fundus angiogram in the early phase (40 s after dye injection) showing filling defect as a patchy pattern. *Bottom left* Optical coherence tomography showing diffuse retinal thickening and disappearance of the inner segment/outer segment line. *Bottom right* Single-flash electroretinograms showing reduced amplitude and delayed implicit time of *a*- and *b*-waves in the right eye

Although various ocular symptoms were reported following a dissection of the ICA, a complete occlusion of the retinal artery or ophthalmic artery are rare [2–4] because of collateral vessels and retrograde blood flow [1]. Generally, ophthalmic symptoms usually occur in combination with other systemic signs, e.g., pulsatile tinnitus, cranial nerve palsy, head, facial, and neck pain. Thus, these changes indicate that the ocular symptoms should not be overlooked as a first indication of an ICA dissection [1, 5, 6].

In our case, an acute painless ophthalmic artery occlusion was the only clinical manifestation. We emphasize that ophthalmologist should be aware that a spontaneous ICA dissection may be the cause of ocular ischemic syndrome even in a young, otherwise healthy individuals.

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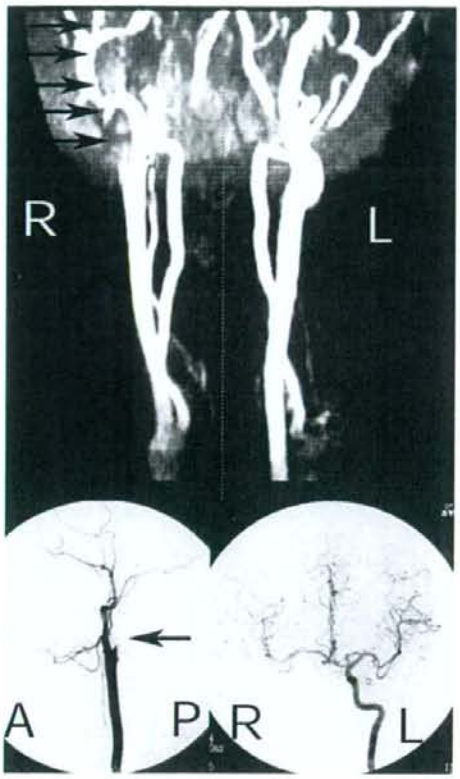

Fig. 2 Magnetic resonance angiography (MRA) of the cervix and brain, and cerebral angiography in the patient. *Top* MRA showing complete occlusion of the right internal carotid artery (ICA) indicated by *arrows*: *R* right, *L* left. *Bottom* The lateral view of the cerebral angiogram showing complete obstruction and swelling at the beginning of right ICA indicated by *arrow* (*left*). Front view of the left ICA angiogram showing intact filling of the right cerebral artery through collateral vessels from the left ICA (*right*): *A* anterior, *P* posterior, *R* right, *L* left

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Jamming of 25-gauge instruments in the cannula during vitrectomy for vitreous haemorrhage

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ABSTRACT.

Purpose: **To report the jamming of 25-gauge instruments in the cannula during vitreous surgery for non-clearing vitreous haemorrhage.**

Methods: **Forty-five eyes underwent vitrectomy with 25-gauge instruments for non-clearing vitreous haemorrhage (VH group). The incidence of 25-gauge instruments jamming in the cannula was determined retrospectively and compared with that in 112 eyes that underwent vitrectomy for epiretinal membrane (ERM group), also using 25-gauge instruments.**

Results: **The 25-gauge vitreous cutter or light pipe became jammed in the cannula in three eyes (7%) in the VH group and the instrument locked inside the cannula had to be removed with the cannula. None of the 25-gauge instruments in the ERM group jammed ($p = 0.022$, Fisher's exact probability test). Two of three eyes developed giant retinal breaks near the sclerotomy but no retinal break related to the sclerotomy was detected in the ERM group. Examination of the cutter revealed blood trapped between the cutter and the cannula.**

Conclusions: **Twenty-five gauge instruments may become jammed in the cannula in eyes with non-clearing vitreous haemorrhage. Clinicians should be aware of this surgical complication when 25-gauge instruments are used in vitreous haemorrhage.**

Key words: 25-gauge – cannula – instrument – vitreous cutter – vitreous haemorrhage

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Introduction

The 25-gauge vitrectomy system was developed to minimize the invasiveness of vitrectomy and to permit transconjunctival sutureless vitrectomy (Fujii et al. 2002a). The initial surgical outcomes and longterm results of 25-gauge systems indicated that they were efficacious for various vitreoretinal disorders (Fujii et al. 2002b; Ibarra et al. 2005; Lakhanpal et al. 2005). However, the smaller diameter of these instruments made them more fragile, and they were more easily bent or damaged (Inoue et al. 2004). Several improvements have been made and their use has been extended to other intraocular surgical procedures (Shimada et al. 2005; Rizzo et al. 2006; Yoon et al. 2006).

The 25-gauge vitrectomy system is useful because it allows for a more tightly closed surgical field than can be achieved with the 23- or 20-gauge vitrectomy systems. This makes higher vacuum aspiration possible as a smaller amount of irrigating fluid escapes from the smaller scleral ports (Fujii et al. 2002a). To accomplish this, 25-gauge instruments are made to fit the cannula very closely, but this close fit may lead to surgical complications.

We experienced 25-gauge vitreous cutters becoming jammed in the cannula during vitreous surgery for dense vitreous haemorrhage. The incidence and possible causes of this jamming were retrospectively investigated, and the results compared with the incidence during surgery for epiretinal membrane without vitreous haemorrhage.

Materials and Methods

The 25-gauge instruments were used in 45 eyes of 39 patients who underwent vitrectomy from April 2004 to March 2006 for non-clearing, dense vitreous haemorrhages (VH group), which prevented a detailed view of the fundus by ophthalmoscopy. Informed consent was obtained from all

patients. The results from these eyes were retrospectively reviewed and compared with those from 112 eyes of 109 patients who underwent 25-gauge vitrectomy for epiretinal membrane (ERM group) during the same period. This was a consecutive series in which all surgery was performed by two of the authors (MI and HS) with similar surgical experience.

The surgeries were performed with 25-gauge vitreous cutters made by the Dutch Ophthalmic Research Center, International b. v. (DORC, International) (Zuidland, the Netherlands), Alcon Laboratories, Inc. (Fort Worth, TX, USA) and Medical Instrument Development Laboratiories (Midlabs), Inc. (San Francisco, CA, USA). The Alcon and DORC vitreous cutters are driven by Accurus (Alcon Corp.) and the Midlab cutter is driven by CV-24000 (NIDEK Corp., Nagoya, Japan). The 25-gauge cannulas were manufactured by DORC or Alcon.

The incidence of the jamming of 25-gauge instruments in the cannula was determined and possible causes investigated. Eyes that had undergone previous vitreous surgery were excluded. Statistical analysis was performed by the chi-square test, Wilcoxon's rank test and Fisher's exact probability test.

In four eyes in the VH group, the peripheral vitreous around the cannula was cut as soon as the vitreous cutter was inserted into the vitreous cavity and before the central vitreous was removed (pre-removed group). In the other 41 eyes in the VH group and all eyes in the ERM group, a routine vitrectomy procedure (i.e. removal of the central vitreous followed by removal of the peripheral vitreous) was used.

Table 1. Characteristics of the vitreous haemorrhage and epiretinal membrane groups.

	VH group	ERM group	p-value
Cases (eyes)	39 (45)	109 (112)	
Age (years)	64.8 ± 13.8	63.9 ± 12.0	0.802*
Gender (male/female)	21/18	52/57	0.577†
Cannula system (DORC/Alcon)	21/24	62/60	0.728†
Incidence of jamming (eye)	3/45	0/112	0.022†

* Wilcoxon's rank test; † Fisher's exact probability test.
VH = vitreous haemorrhage; ERM = epiretinal membrane.

Results

The mean age of the patients was 64.8 ± 13.8 years in the VH group and 63.9 ± 12.0 years in the ERM group ($p = 0.802$, Wilcoxon's rank test (Table 1). There were 21 men and 18 women in the VH group and 52 men and 57 women in the ERM group ($p = 0.577$, Fisher's exact probability test). The non-clearing vitreous haemorrhages in the VH group were caused by diabetic retinopathy in 22 eyes, branch retinal vein occlusion in 10 eyes, uveitis in four eyes, central retinal vein occlusion in three eyes, age-related macular degeneration in three eyes, rhegmatogenous retinal detachment in two eyes, and subarachnoid haemorrhage (Terson syndrome) in one eye (Table 2). Preoperative best corrected visual acuity (BCVA) in the affected eyes in the VH group was: light perception in seven eyes; hand motion in 26 eyes; counting fingers in four eyes; 0.01 in five eyes, and 0.02 in three eyes.

The cannula system manufactured by DORC International was used in 21 eyes in the VH group and 62 eyes in the ERM group; that made by Alcon was used in 24 eyes in the VH group and 60 eyes in the ERM group ($p = 0.728$, Fisher's exact probability test).

The 25-gauge vitreous cutter or the light pipe became jammed and/or blocked in the cannula intraoperatively in three eyes (7%) in the VH group and no eyes in the ERM group (Table 1) ($p = 0.022$, Fisher's exact probability test). When the instruments that jammed in the three eyes in the VH group were examined, a viscous, pigmented substance was found to be trapped in the cannula. The cutters in these cases had been made by Midlabs and Alcon (cases 29 and 30), and the light pipe by Alcon (case 33). The instruments that completely jammed in the cannula were made by Alcon (Table 2). It was impossible to either rotate or remove the cutter or the light pipe from the cannula (Fig. 1A). Thus, the jammed cannula

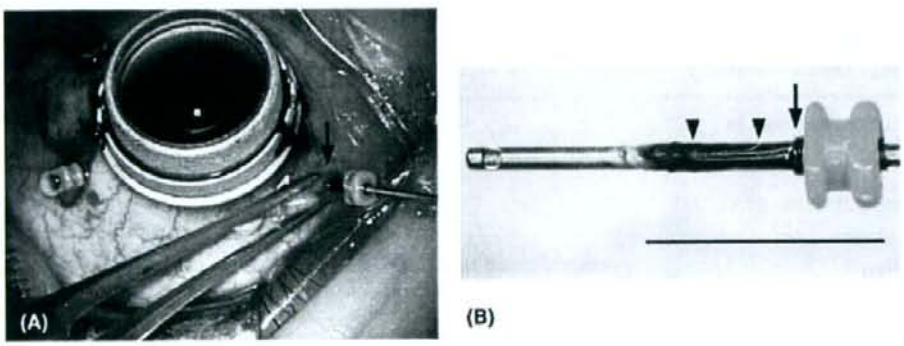

Fig. 1. (A) The 25-gauge vitreous cutter (Midlabs) jammed intraoperatively inside the cannula (Alcon) and was removed with the cannula. The inside of the cannula is black because of entrapped vitreous haemorrhage (arrow). (B) Once removed, the cutter shows haemorrhage trapped between the inner tube of the cannula and the cutter tube (arrowheads). The inner tube was folded at the plug connection (arrow) by the twisting exerted when it was removed from the cutter. (Scale bar: 5.0 mm.)

Table 2. Characteristics of cases in the vitreous haemorrhage group.

Case	Age (years)	Sex	Duration (months)	Disorder	Preop BCVA	Resistance of cannula	Cutter*	Cannula† and light pipe	Preoperative procedure‡
1	72	F	2	BRVO	0.01	–	DORC	DORC	Conv
2	49	F	6	PDR	HM	–	DORC	DORC	Conv
			2	PDR	HM	–	Alcon	Alcon	Conv
3	86	F	4	PDR	HM	–	DORC	DORC	Conv
			24	PDR	LP	–	DORC	DORC	Conv
4	51	M	1.5	PDR	HM	–	DORC	DORC	Conv
5	85	M	12	CRVO	HM	Resistant	DORC	DORC	Conv
6	60	F	1.3	Uveitis	LP	–	DORC	DORC	Conv
7	49	F	1.3	Uveitis	HM	–	DORC	DORC	Conv
			1.3	Uveitis	HM	–	DORC	DORC	Conv
8	63	M	21	PDR	LP	–	DORC	DORC	Conv
9	67	M	4.5	Terson	0.01	–	DORC	DORC	Conv
10	76	F	6	BRVO	HM	–	DORC	DORC	Conv
11	84	F	7	PDR	0.02	–	DORC	DORC	Conv
12	71	M	3	AMD	HM	–	DORC	DORC	Conv
13	74	F	1	PDR	CF	–	DORC	DORC	Conv
14	61	M	1.1	PDR	HM	–	DORC	DORC	Conv
15	74	M	3	PDR	0.01	–	DORC	DORC	Conv
			7	PDR	HM	–	Alcon	Alcon	Conv
16	84	F	2	PDR	CF	–	DORC	DORC	Conv
17	56	F	3.3	BRVO	CF	–	DORC	DORC	Conv
18	87	M	5	CRVO	LP	Resistant	DORC	DORC	Conv
19	60	F	12	PDR	HM	–	DORC	DORC	Conv
			12	PDR	0.02	–	Alcon	Alcon	Conv
20	55	F	4	PDR	0.01	–	Alcon	Alcon	Conv
21	83	M	6	BRVO	HM	–	Alcon	Alcon	Conv
22	54	F	1.8	BRVO	HM	–	Alcon	Alcon	Conv
23	74	M	2	CRVO	LP	Resistant	Alcon	Alcon	Conv
24	63	F	1	RRD	HM	–	Midlabs	Alcon	Conv
25	78	M	1.3	BRVO	0.01	–	Alcon	Alcon	Conv
26	70	M	0.9	AMD	LP	Resistant	Alcon	Alcon	Conv
27	38	F	6	PDR	HM	–	Alcon	Alcon	Pre-removed
28	68	F	12	Uveitis	HM	–	Alcon	Alcon	Conv
29	56	M	2.6	BRVO	LP	Jamming	Alcon	Alcon	Conv
30	54	M	1	BRVO	HM	Jamming	Midlabs	Alcon	Conv
31	73	M	1	AMD	HM	–	Alcon	Alcon	Pre-removed
32	61	F	1	BRVO	HM	–	Midlabs	Alcon	Pre-removed
33	64	F	6	BRVO	HM	Jamming	Midlabs	Alcon	Conv
34	68	M	0.9	RRD	HM	–	Midlabs	Alcon	Conv
35	34	M	2	PDR	HM	–	Midlabs	Alcon	Conv
36	57	M	2	PDR	HM	–	Midlabs	Alcon	Conv
			0.8	PDR	HM	–	Midlabs	Alcon	Conv
37	36	M	3	PDR	CF	–	Midlabs	Alcon	Conv
38	74	M	1	PDR	0.02	–	Midlabs	Alcon	Conv
39	62	M	2	PDR	HM	–	Midlabs	Alcon	Pre-removed

* Cutter: manufacturer of the vitreous cutter.

† Cannula: manufacturer of the cannula.

‡ Pre-removed: peripheral vitreous was removed prior to core vitrectomy; Conv: conventional vitrectomy in which peripheral vitreous was not removed prior to core vitrectomy.

M = male; F = female; BRVO = branch retinal vein occlusion; PDR = proliferative diabetic retinopathy; CRVO = central retinal vein occlusion; AMD = age-related macular degeneration; RRD = rhegmatogenous retinal detachment; BCVA = best corrected visual acuity; HM = hand motion; LP = light perception; CF = counting fingers.

had to be removed and replaced with a new cannula of the same type, and the cutter or light pipe re-inserted at the original sclerotomy site in order to continue the vitrectomy.

Retinal breaks with a localized retinal detachment were found in two of the three eyes in which instruments jammed, although none of the retinal breaks were related to the sclerotomy in the ERM group. Vitreous haemorrhage developed in these eyes as a result of branch retinal vein occlusion. These retinal breaks were located at the vitreous base where the cannula was inserted and became jammed (Fig. 2). Both eyes were treated by explanting an encircling buckle followed by gas or silicone oil tamponade.

No complications were seen in the other 42 eyes (83%) in the VH group. However, the 25-gauge vitreous cutter and light pipe were resistant to movement within the cannula in four other eyes (12%) in the VH group. In these four eyes, the surgery was successfully

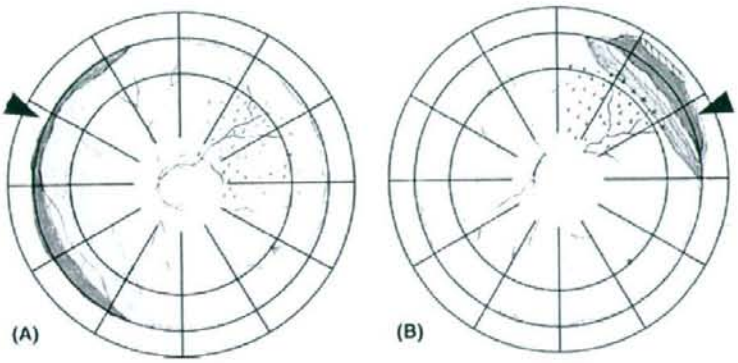

Fig. 2. Fundus charts for two patients with retinal breaks. (A) Chart for the patient in Fig. 1. The vitreous cutter was stuck inside the cannula (arrowhead) and a giant retinal break was found intraoperatively. The patient was treated with an encircling buckle and silicon oil tamponade. (B) The light pipe was stuck inside the cannula (arrowhead) and a giant retinal break was found intraoperatively. This patient was treated with encircling buckle and gas tamponade.

performed by carefully removing the peripheral vitreous around the cannula until the irrigating solution was seen to flow continuously out of the eye. The surgical instruments did not jam in the four eyes (pre-removed group) in which the peripheral vitreous around and inside the cannula had been removed before the core vitrectomy. However, because of the small number of cases in the pre-removed group, this incidence did not differ significantly from that of the conventional group ($p = 0.37$, chi-square test).

The incidence of jamming or resistance to movement in the VH group did not differ significantly between the cutters manufactured by DORC (two of 21 eyes), Alcon (three of 13 eyes) or Midlabs (two of 11 eyes) ($p = 0.41$, DORC versus Alcon; $p = 0.77$, Alcon versus Midlabs; $p = 0.48$, DORC versus Midlabs; chi-square test) or between the cannulas manufactured by DORC (two of 21 eyes) or Alcon (five of 24 eyes) ($p = 0.30$, chi-square test).

The incidence of jamming or resistance to movement did not differ significantly between the group with preoperative vision poorer than hand motion (seven of 33 eyes) and the group with VA better than finger counting (none of 12 eyes; $p = 0.08$, chi-square test). The morbidity period of visual deterioration was 6.3 ± 3.7 months in cases in which the instruments jammed or were resistant and 4.5 ± 3.6 months in cases in which the instruments did not jam or become resistant ($p = 0.86$, unpaired t-test).

Discussion

The 25-gauge vitrectomy system was initially designed to decrease the surgical invasiveness of peripheral vitrectomy. However, refinements in the instruments and techniques have expanded their surgical use (Shimada et al. 2005). To increase the efficiency of smaller diameter instruments, the cannula was made to fit the diameter of the instruments more closely (Fujii et al. 2002a). The inner diameter of the DORC cannula is 0.53 mm and that of the Alcon 0.54 mm. However, in outer diameter, the DORC vitreous cutter measures 0.51 mm and the Alcon and Midlabs cutters measure 0.52 mm, according to the specifications given in their respective catalogues. This tight fit results in a decrease in the leakage of intraocular irrigating fluid, which should stabilize intraocular pressure during vitrectomy with high-vacuum aspiration (Fujii et al. 2002a).

However, when dense vitreous haemorrhage is removed during vitrectomy, the thick haemorrhage and condensed peripheral vitreous around the cannula may become trapped in the inner tube of the cannula by repeated movements of the vitreous cutter or light pipe through the cannula. This phenomenon was not specific to the cannula system of a particular manufacturer, as we had similar experiences with both the Alcon and DORC cutters. However, a higher incidence was found in eyes with poorer preoperative vision or with a longer postoperative morbidity period of visual deterioration. One of the reasons for this may be that preoperative vision may be correlated with the degree of condensed vitreous or blood clots. However, we were unable to determine the significance of this hypothesis because of the small number of eyes.

Once the vitreous cutter is jammed in the cannula, the cannula may damage the sclerotomy site, resulting in possible peripheral retinal breaks or oral dialysis. Electromicroscopic examinations have revealed the entrapment of vitreous at the sclerotomy site after conventional vitrectomy (Koch et al. 1995). However, biomicroscopic analyses revealed no significant difference between conventional vitrectomy and sutureless 25-gauge vitrectomy (Kwok et al. 2001). The trapped vitreous with haemorrhage at the cannula may cause peripheral retinal breaks as well as the entrapment of vitreous at the sclerotomies (Liu et al. 2004; Wimpissinger & Binder 2007).

Conclusions

Clinicians should be aware that 25-gauge instruments may become jammed in the cannula when surgerys is performed in eyes with non-clearing vitreous haemorrhage or thickened vitreous. To avoid this, we recommend the removal of vitreous around the cannula prior to central vitrectomy, especially in eyes with massive vitreous haemorrhage with poorer preoperative vision and a longer morbidity period of visual deterioration. Because of the small number of eyes included in this study, further prospective randomized studies to evaluate the efficacy of these surgical instruments are needed.

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Visual recovery after vitrectomy for macular hole using 25-gauge instruments

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ABSTRACT.

Purpose: **To determine whether vitrectomy with 25-gauge instruments contributes to better postoperative visual recovery after macular hole (MH) surgery.**

Methods: **The medical records for 46 consecutive eyes operated for MH by a single surgeon were retrospectively examined. Vitrectomy had been performed with a 25-gauge instrument in 23 eyes (25-G group) and with a 20-gauge instrument in 23 eyes (20-G group). Postoperative visual acuity (VA) in logMAR (logarithm of the minimum angle of resolution) units after 1 week and 1, 3, 6, 9 and 12 months, operating time, and volume of intraocular irrigating fluid were compared between the two groups.**

Results: **Mean preoperative logMAR VA was 0.72 in the 25-G group and 0.68 in the 20-G group ($p = 0.282$, unpaired *t*-test). One week after surgery, VA was significantly better in the 25-G group (0.40 ± 0.34) than in the 20-G group (0.58 ± 0.30) ($p = 0.020$). This significant difference was maintained until 9 months after surgery, but was no longer evident at 12 months ($p = 0.182$). Operating time was significantly shorter in the 25-G group (56 ± 16 mins) than in the 20-G group (85 ± 28 mins) ($p = 0.003$, unpaired *t*-test). The volume of intraocular irrigating fluid was significantly less in the 25-G group (244 ± 72 ml) than in the 20-G group (416 ± 113 ml) ($p < 0.0001$).**

Conclusions: **The use of 25-gauge vitrectomy instruments leads to better postoperative visual recovery following surgery for MH during the first 9 months, probably as a result of shorter surgical time and a lower volume of intraocular irrigating fluid.**

Key words: 25-gauge vitrectomy – macular hole – postoperative recovery – postoperative complications

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Introduction

Twenty-five gauge surgical instruments were introduced for vitreal surgery in 1990 to facilitate delicate vitreoretinal dissections, particularly at the vitreous base and when fibrovascular tissues were closely adherent to the retina (De Juan & Hickingbotham 1990). Because of their smaller size, these instruments were more precise in their cutting capabilities than other instruments (De Juan & Hickingbotham 1990). Further improvements were made in the instruments, with the development of a 25-gauge transconjunctival sutureless vitrectomy system (Millennium TSV25™; Baush & Lomb, NY, USA) to replace 20-gauge instruments in selected cases because they were considered less invasive (Fujii et al. 2002a, 2002b). Recent analyses have shown the longterm results after 25-gauge vitrectomy to be effective and safe (Ibarra et al. 2005; Lakhanpal et al. 2005). The recent improvements in 25-gauge vitreous instruments have expanded the indications for 25-gauge vitreous surgeries (Shimada et al. 2005).

The 25-gauge vitreous system uses smaller incisions that allow transconjunctival sutureless sclerotomies, which has led to a reduction in postoperative corneal astigmatism. In addition, the volume of intraocular irrigating fluid used during 25-gauge vitrectomy is believed to be less than that required with the 20-gauge system. These differences between the 25- and 20-gauge instruments should make visual recovery better with the 25-gauge system, but this has not been quantified for macular hole (MH) surgery. Thus, the purpose of this study was to compare postoperative visual events after MH surgery with 25- and 20-gauge instruments.

Materials and Methods

The medical records of 46 consecutive eyes which had undergone vitrectomy with 25- or 20-gauge vitrectomy instruments for an MH, carried out by a single surgeon (MI), and which had been followed for at least 1 year were examined. All patients were fully informed about the treatment protocol and gave signed informed consent. The patients were not randomly divided into the two treatment groups. We used 20-gauge vitrectomy in the early period and then changed to 25-gauge vitrectomy for macular hole surgery. Thus, these two groups were divided by the earlier and later periods. The procedures used conformed to the tenets of the Declaration of Helsinki.

The 25-gauge vitrectomy system (DORC International, Zuidland, the Netherlands) was used in 23 eyes (25-G group) and the 20-gauge vitrectomy system (1500 cutter; Alcon Corp., Fort Worth, TX, USA) was used in 23 eyes (20-G group). Simultaneous cataract surgery was performed if the lens was even mildly cataractous to avoid postoperative progression of a nuclear cataract. Patients with more than moderate cataract (> 3 Emery grade) were excluded.

The surgical procedures were similar for both systems. The inner limiting membrane (ILM) was removed without indocyanine green or triamcinolone acetonide staining in all cases. A triangular flap was created by gasping the ILM with an end-gripping forceps (20-G or 25-G; DORC International) and peeling it off circumferentially for approximate 2 disc diameters (DD) around the macular hole. The peeling was performed in a manner similar to that used in the continuous curvilinear capsulorhexis of the anterior lens capsule process during cataract surgery. The border between the peeled and unpeeled areas was identified by a wrinkled reflex on the retinal nerve fibre layer.

Peripheral vitreous was removed through the ora serrata in each group with scleral indentation and endophotocoagulation was applied if peripheral retinal breaks were present. The surgery was completed with an exchange of air for vitreous fluid. In the eyes with peripheral retinal breaks, 10% SF6 gas was injected for tamponade. The patients were instructed to maintain a facedown position for 3 days. In two eyes with peripheral retinal breaks, the 25-G sclerotomy was enlarged to 20-G in order to insert a 20-G endolaser probe with endoillumination. These sclerotomies were sutured in the usual manner. Sutures were not used in any other eyes in the 25-G group, including those eyes with retinal breaks treated with a 25-G endolaser probe.

The two groups were compared for patient age, morbidity period, stage of macular hole and observation period. The stage and closure of the macular hole was confirmed by ophthalmoscopy and optical coherence tomography (OCT). Preoperative best corrected visual acuity (BCVA) in logMAR units (logarithm of the minimum angle of resolution) was compared with postoperative BCVA after 1 week and 1, 3, 6, 9 and 12 months. In addition, operating time, volume of intraocular irrigating balanced salt solution (BSS) plus surgery-induced astigmatism (i.e. postoperative astigmatism subtracted from preoperative astigmatism, obtained at the same axis using an autorefractometer [ARK-700 A; Nidek Co., Ltd, Aichi, Japan]) were compared. The incidence of peripheral retinal breaks including sclerotomy-related retinal breaks was evaluated. Sclerotomy-related retinal breaks were defined as oral dialysis or peripheral retinal breaks located at the vitreous base close to the sclerotomy.

Statistical analyses

Unpaired *t*-test or chi-square test was used for statistical analysis. A p-value < 0.05 was defined as statistically significant.

Results

Preoperative values

The demographics of patients in the two groups are presented in Table 1. Their mean age was 64.7 ± 6.4 years in the 25-G group and 67.5 ± 7.1 years in the 20-G group ($p = 0.200$) (Table 1). The preoperative stage of macular hole did not differ significantly between the two groups ($p = 0.809$). Simultaneous cataract surgery was performed in 20 eyes in the 25-G group and 18 eyes in the 20-G group ($p = 0.437$). The morbidity period was 2.6 months in the 25-G group and 3.2 months in the 20-G group ($p = 0.504$).

Macular hole closure

The macular hole was closed after the first surgery in 22 of 23 eyes in the 25-G group (96%) and 22 of 23 eyes in the 20-G group (96%). This difference was not significant ($p > 0.999$, chi-square test). In the two eyes in which the macular hole was not closed, the hole was successfully closed by a second surgery. The additional surgery was performed with the 25-gauge vitrectomy system in the 25-G group and with the 20-gauge vitrectomy system in the 20-G group.

Visual acuity

The mean preoperative logMAR vision was 0.72 in the 25-G group and 0.68 in the 20-G group ($p = 0.282$) (Table 1). At 1 week, postoperative vision could be measured through a residual gas bubble in all eyes, and the mean postoperative logMAR VA improved to 0.40 ± 0.34 in the 25-G group and 0.58 ± 0.30 in the 20-G group (Fig. 1, Table 2). At 1 month, mean

Table 1. Preoperative values in both groups.

		25-G group	20-G group	p-value
Age (years)		64.7 ± 6.4	67.5 ± 7.1	0.200*
Morbidity period (months)		2.6 ± 7.8	3.2 ± 4.2	0.504*
Stage of macular hole	I	0	0	0.809†
	II	6	5	
	III	16	16	
	IV	1	2	
Preoperative VA (logMAR)		0.72 ± 0.36	0.68 ± 0.27	0.282*
Simultaneous cataract surgery		20 (87%)	18 (78%)	0.437†
Observation period (months)		17.3 ± 2.7	19.8 ± 6.8	0.096*

* p-value according to unpaired *t*-test.
† p-value according to chi-square test.
VA = visual acuity.

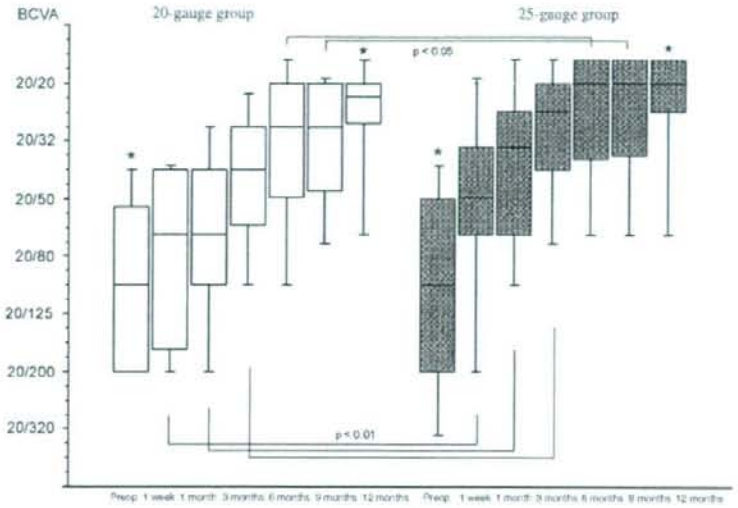

Fig. 1. Mean pre- and postoperative best corrected visual acuity (BCVA). Postoperative BCVA is significantly better than preoperative BCVA in the 25-G group at 1 week and at 1, 3, 6 and 9 months, but not at 12 months ($p < 0.05$, unpaired *t*-test). * Not significant.

Table 2. Post-surgery visual improvement in logMAR units.

Visual acuity	25-G group	20-G group	p-value*	p-value†	p-value‡	p-value§
Preoperative	0.72 ± 0.36	0.68 ± 0.27				
Postoperative						
1 week	0.40 ± 0.34	0.58 ± 0.30	0.020			
1 months	0.28 ± 0.27	0.49 ± 0.29	0.001	0.499		
3 months	0.18 ± 0.25	0.34 ± 0.27	0.004	0.794	0.245	
6 months	0.11 ± 0.25	0.25 ± 0.31	0.023	0.511	0.265	0.344
9 months	0.10 ± 0.24	0.23 ± 0.27	0.032	0.531	0.080	0.146
12 months	0.09 ± 0.23	0.15 ± 0.27	0.182	0.086	0.011	0.004

* p-value by comparison with preoperative vision according to unpaired *t*-test.
† p-value by comparison with postoperative VA at 1 week according to unpaired *t*-test.
‡ p-value by comparison with postoperative VA at 1 month according to unpaired *t*-test.
§ p-value by comparison with postoperative VA at 3 months according to unpaired *t*-test.
VA = visual acuity.

postoperative VA in logMAR units improved to 0.28 ± 0.27 in the 25-G group and 0.49 ± 0.29 in the 20-G group. The improvement in BA was significantly better at both time-points in the 25-G group ($p = 0.020$, $p = 0.001$, respectively). This significant difference in visual improvement was maintained at 3, 6 and 9 months after surgery ($p = 0.004$, $p = 0.023$, $p = 0.032$, respectively), but, at 12 months, the visual improvement did not differ significantly between the two groups ($p = 0.182$). However, VA at 12 months compared with postoperative VA at 1 and 3 months was significantly better in the 20-G group than in the 25-G group ($p = 0.011$, $p = 0.004$, respectively) (Fig. 1, Table 2). This significant difference indicated that the visual improvement in 25-G group was achieved during an earlier postoperative period (from 1 week to 3 months), but not from 6 to 12 months.

Postoperative VA > 20/20 was achieved in 15 eyes (65%) in the 25-G group and 10 eyes (43%) in the 20-G group ($p = 0.139$) (Fig. 2). Postoperative VA > 20/25 was achieved in 18 eyes (78%) in the 25-G group and 16 eyes (70%) in the 20-G group ($p = 0.502$).

Operating time and volume of irrigating fluid

Table 3 shows operating time and volume of intraocular irrigating fluid for each group. Operating time was significantly shorter in the 25-G group ($p = 0.003$). Operating time in patients who underwent simultaneous cataract surgery was also significantly shorter in the 25-G group than in the 20-G group ($p = 0.002$). Operating time in the patients who did not undergo simultaneous cataract surgery was also significantly shorter in the 25-G group ($p = 0.049$).

The volume of intraocular irrigating fluid in the 25-G group was significantly less than in the 20-G group ($p < 0.0001$). The volume of intraocular irrigating fluid in patients who underwent simultaneous cataract surgery in the 25-G group was significantly less than that in the 20-G group ($p < 0.0001$). The volume of intraocular irrigating fluid used in patients who did not have simultaneous cataract surgery in the 25-G group was also significantly less than that in the 20-G group ($p = 0.006$).

Surgery-induced astigmatism and intraoperative retinal breaks

The mean surgery-induced astigmatism in the 25-G group was 0.39 ± 0.30 dioptres (D) at postoperative week 1, 0.43 ± 0.29 D at 1 month, 0.36 ± 0.33 D at 3 months; parallel figures for the 20-G group were 0.88 ± 0.71 D, 0.54 ± 0.48 D and 0.52 ± 0.49 D, respectively (Fig. 3). Surgery-induced astigmatism was significantly lower in the 25-G group at postoperative week 1 ($p = 0.009$, unpaired *t*-test), but not at 1 and 3 months ($p = 0.391$, $p = 0.272$, respectively; unpaired *t*-test).

Peripheral retinal breaks were found intraoperatively in four eyes (17%) in the 25-G group and five eyes (22%) in the 20-G group ($p = 0.710$) (Table 3). However, none of the eyes in the 25-G group developed retinal breaks related to the sclerotomy, whereas three eyes (13%) in the 20-G group did, although this was not significant ($p = 0.073$).

Discussion

Our results showed that the vitrectomy performed with the 25-gauge system led to significantly better VA during the first 9 months after surgery than conventional 20-G vitrectomy. However, at 12 months, VAs were not significantly different with the two

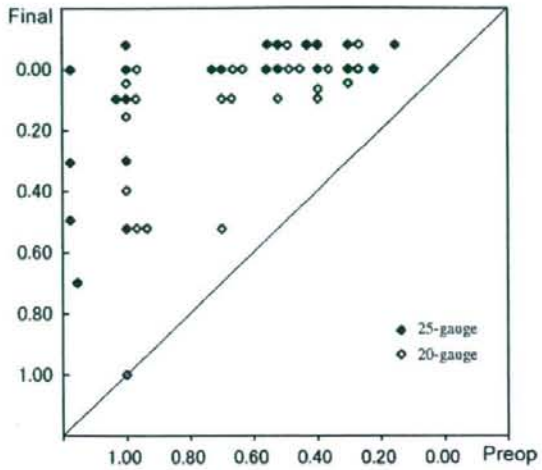

Fig. 2. Preoperative and final best corrected visual acuity (BCVA). The differences in numbers of eyes with postoperative BCVA > 20/20 and > 20/25 were not significant in the two groups ($p = 0.183$, $p = 0.889$, respectively; chi-square test).

Table 3. Operating time and volume of intraocular irrigating fluid in both groups.

	25-G group	20-G group	p-value
Operating time (mins)	56 ± 16	85 ± 28	0.003*
With cataract surgery	58 ± 16	90 ± 30	0.002*
Without cataract surgery	42 ± 14	64 ± 7	0.049*
Volume of intraocular irrigating fluid (ml)	244 ± 72	416 ± 113	< 0.0001*
With cataract surgery	258 ± 60	450 ± 100	< 0.0001*
Without cataract surgery	110 ± 14	281 ± 24	0.006*
Eyes with peripheral retinal breaks	4 (17%)	5 (22%)	0.710†
Eyes with sclerotomy-related retinal breaks	0 (0%)	3 (13%)	0.073†

* p-value according to unpaired *t*-test.
† p-value according to chi-square test.

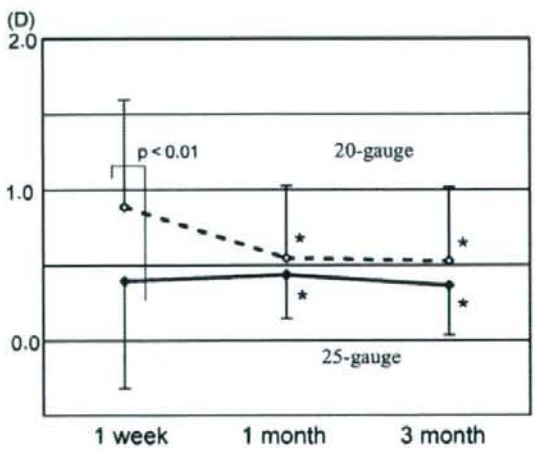

Fig. 3. Postoperative surgery-induced astigmatism. Surgery-induced astigmatism was significantly less in the 25-G group at postoperative week 1 ($p = 0.009$, unpaired *t*-test), but the difference between the two groups was not significant at 1 and 3 months ($p = 0.391$, $p = 0.272$, unpaired *t*-test). * Not significant.

vitrectomy systems. Kadonosono et al. (2006) reported better VA after 25-G vitrectomy than after the 20-G procedure at 1 month but not at 6 months for patients with an epiretinal membrane (ERM). Rizzo et al. (2006) reported rapid visual improvement and less postoperative discomfort after 25-gauge vitrectomy, with shorter surgical time and less intraoperative use of BSS in patients with an ERM.

Our patients underwent macular hole surgery, which required more complicated surgical procedures than does surgery for ERM, such as the thorough removal of peripheral vitreous, subsequent gas tamponade and facedown positioning. This would suggest that 25-G vitrectomy results in better visual outcomes during the early period after more complicated surgery.

The better results observed with 25-G vitrectomy may be partly explained by the fact that it requires less irrigating fluid and surgical time. Negi et al. (1981) reported a decrease in the amplitudes of electroretinograms (ERGs) after intraocular irrigation with Ringer's solution or BSS in rabbit eyes, although the reduction was smaller than that after irrigation with physiological saline. When retinal oedema was induced by perfusion with different intraocular solutions for different durations in albino rabbits, Ringer's lactate and physiological saline solutions were reported to lead to more oedema than BSS-plus and the induced oedema was more severe with longer perfusion times (Saornil Alvarez & Pastor Jimeno 1987). In addition, intraocular irrigating solution at operating room temperature has been reported to decrease the temperature in the human vitreous cavity to 27–28 °C, which led to markedly delayed peak time latencies and reduced ERG amplitudes, although the functional changes were reversible (Horiguchi & Miyake 1991). Thus, the reduction in the volume of intraocular irrigating fluid and the duration of irrigation may minimize the surgical invasiveness of 25-G vitrectomy, as is supported by our results.

The surgery-induced astigmatism was also significantly lower in the 25-G group at postoperative week 1, but not at 1 and 3 months. Better visual recovery after 25-gauge vitrectomy may also be related to the lower

postoperative astigmatism, especially in the short term. However, further studies should be performed to evaluate the efficacy of 25-gauge vitrectomy because most of our cases involved simultaneous cataract surgery.

One other advantage of 25-G vitrectomy concerns the size of the cannula, which reduced the incidence of sclerotomy-related retinal breaks (Machemer & Hickingbotham 1985; Territo et al. 1997). In our study, none of the eyes in the 25-G group developed sclerotomy-related retinal breaks, although three eyes in the 20-G group developed retinal breaks ($p = 0.073$). Scartozzi et al. (2007) described a tendency towards a lower incidence of intraoperative sclerotomy-related retinal breaks, single or multiple, with 25-gauge vitrectomy compared with 20-gauge vitrectomy for macular surgery, but the differences were not significant. When iatrogenic retinal breaks are found, careful vitreous shaving around the retinal breaks and additional surgical procedures including endophotocoagulation under fluid–air exchange are mandatory. This leads to an increase in operating time and volume of intraocular irrigating fluid. It may also increase the risk of temporal visual field defects after retinal dehydration by air infusion (Kerrison et al. 1997).

Thus, 25-gauge vitrectomy has several advantages: it is less invasive to the ocular surface; requires less surgical time, and uses a lower volume of irrigating fluid. All of these differences benefit the ocular surface and the neural retina, which may then result in better and earlier functional recovery after surgery.

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原著

網膜電気刺激の臨床応用

—Clinical application of the electrical retinal stimulation—

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要旨

種々の網膜視神経疾患に対して経角膜網膜電気刺激を行った。陳旧性の網膜動脈閉塞症や視神経萎縮において自他覚的視機能改善を認め，本治療法の有効性が示唆された。

目　的：網膜電気刺激はphospheneと呼ばれる自覚的な感覚と，皮質での誘発脳波を惹起することが知られている。近年，経角膜電気刺激（以下TES）が網膜のIGF-1を誘導すること，神経保護作用を有することから視神経症に対する治療応用も報告された。我々は種々の網膜視神経疾患にTESを行い治療効果を検討した。

方　法：網膜色素変性症，網膜動脈閉塞症，虚血性視神経症，外傷性視神経症，緑内障等計27例30眼に対してTESを行い，治療前後で視力，視野，電気生理学的検査等を行った。

結　果：視力視野等の自覚検査およびERGやVEPなどの他覚検査での改善率はいずれも20～30%であった。

結　論：多くが進行性の疾患であることや，再生しないとされる神経細胞機能の改善の評価は難しいこと，より長期的な評価が必要であることなどが課題と考えられた。また，有効な症例があることが示唆され，さらなる臨床および基礎研究がまたれる。

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はじめに

網膜電気刺激はphospheneと呼ばれる，光覚に似た感覚を惹起する。この自覚的な感覚を他覚的に評価する試みとして，1968年にPottsら[1]は，眼球を電気パルスで刺激することにより人の後頭葉から誘発脳波を記録し，その特性について報告した。これは，electrically evoked response（EER）と呼ばれ，その後三宅ら[2)~6)]がこのEERを，種々の動物や人，および種々の眼疾患患者から体系的に記録した。彼らは，光刺激によって誘発される視覚誘発電位との比

表1　各疾患の臨床的背景

	眼数（例数/眼数）	男女比（眼数）	年齢（歳：平均）	発症からの期間（月数：平均）	治療前視力（中央値）	治療後視力（中央値）
網膜色素変性症	8/8	4：4	18～56 (37.5±13.0)	72～276 (183.1±82.2)	手動弁～0.6 (0.09)	手動弁～0.8 (0.08)
網膜動脈閉塞症	6/7	5：1 (6：1)	27～63 (37.5±13.0)	2～33 (20.0±11.6)	光覚(-)～1.2 (0.06)	光覚(+)～1.2 (0.1)
網膜剝離術後視野障害	1/1	1：0	38	9	0.2	0.5
虚血性視神経症	3/3	2：1	38～77 (58.0±19.5)	11～62 (44.3±28.9)	0.05～0.7 (0.5)	0.05～1.2 (0.6)
外傷性視神経症	3/4	2：1 (2：2)	26～63 (38.3±21.4)	3～21 (12.3±7.9)	光覚(-)～1.2 (0.17)	光覚(-)～1.2 (0.22)
視神経萎縮	2/3	2：0 (3：2)	23，34	8～36 (18.3±15.4)	0.03～0.1 (0.05)	0.04～0.3 (0.1)
緑内障	4/4	4：0	73～77 (75.0±1.7)	—	0.2～1.2 (1.0)	0.2～1.2 (0.9)

較も含め，その詳細な分析によってEERは順応の影響を受けないなどERGとは異なる挙動を示し，源となる網膜の層についても精力的に研究を行った。そして進行した網膜色素変性症や網膜全剝離患者において，たとえERGは記録できなくともEERにより内層網膜の機能を評価できることを報告した。これが我々の知り得る限り，最初の網膜電気刺激の臨床応用であった。これはすなわち，視細胞機能がなくても内層機能が保たれていれば電気刺激によって人工視覚を惹起することができることを意味している。そして20年の時を経て，人工視覚，人工網膜研究[7)~9)]が盛んとなった1990年代後半に再度注目され，網膜色素変性症などで視覚を失った患者への視機能獲得というアイディアにつながった。

一方，人工網膜研究グループのひとつであるChowら[9)]は，網膜下チップを埋植された網膜色素変性症に代表される視細胞変性疾患患者において，網膜下チップによる微少電気刺激を直接受けていない部分の網膜機能も改善することを報告した。これに着目した不二門らのグループが視神経疾患の治療としての神経細胞の電気的賦活を確立しようと種々の研究を重ね，いくつかのエビデンス[10)~13)]を発表した。すなわち，視神経への直接の刺激そして経角膜電気刺激（transcorneal electrical stimulation：以下TES）が網膜のinsulin-like growth factor-1（IGF-1）を誘導する[10)]こと，網膜神経節細胞に対して神経保護作用を有すること[11)]を証明した。さらにTESが外傷性視神経症（traumatic optic neuropathy：TON）や虚血性視神経症（ischemic optic neuropathy：ION）に対して，視力視野などの視機能改善効果があること[13)]を報告した。

そこで我々は，慶應義塾大学医学部倫理委員会の承認のもと，網膜疾患に対する電気刺激治療を行い，陳旧性の網膜動脈閉塞症に対して自覚的にも他覚的にも視機能改善が認められることを報告した[14)]。さらに，視神経疾患や他の網膜疾患に対する治療効果を検討しており，ここでは中間データを供覧することで，TESの臨床応用のひとつとして網膜視神経疾患に対する治療法としての可能性を問いたい。また，角田らが開発した網膜内因性信号計測法（functional

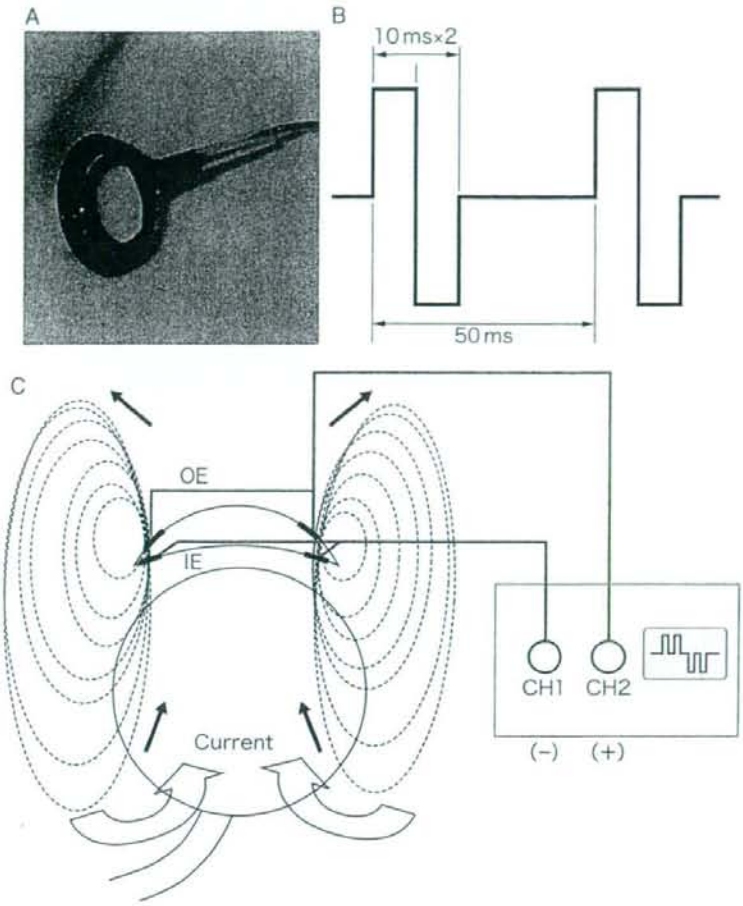

図1　経角膜網膜電気刺激の方法
A：刺激に用いたコンタクトレンズ型電極(メイヨー，稲沢，日本)
B：刺激電流の条件：10 msec/phase，20 Hz，最初に角膜側(コンタクト型電極の内側の電極)を＋，眼瞼側(コンタクト型電極の外側の電極)を－とした二相性刺激(positive first)とした。
C：経角膜網膜電気刺激のシェーマ

retinography：FRG)[15)~17)]を用いて網膜電気刺激による網膜の神経活動をマッピングした。

I. 対象と方法

❶ 治療としての評価

対象とした疾患および症例の内訳を**表1**に示す。網膜色素変性症と緑内障(1眼の正常眼圧緑内障を含む両眼性の原発開放隅角緑内障例および1例の両眼性原発閉塞隅角緑内障)に関しては視力の悪いほうの眼を対象とし，僚眼は対照として視機能を比較した。

方法は，角結膜に点眼麻酔(0.4% oxybuprocaine hydrochloride)を滴下した後，メイヨー社製コンタクトレンズ型電極(メイヨー，稲沢，日本，**図1**)を患眼に装着し，刺激装置(BPG-1，BAK Electronics，Inc.，Mount Airy，MD，USA)およびアイソレーター(BSI-2，BAK

表2　経角膜網膜電気刺激(TES)後の視機能改善の割合

	自覚検査		他覚検査	
	視力	視野	ERG	VEP
網膜色素変性症	0/8 (0)	0/8 (0)	未測定	未測定
網膜動脈閉塞症	3/5 (60.0)	3/5 (60.0)	2/6 (33.3)	0/2 (0)
網膜剝離術後視野障害	1/1 (100)	1/1 (100)	未測定	未測定
網膜疾患	4/14 (28.6)	4/14 (28.6)	2/6 (33.3)	0/2 (0)
虚血性視神経症	1/3 (33.3)	2/3 (66.7)	未測定	0/3 (0)
外傷性視神経症	0/3 (0)	0/3 (0)	未測定	0/4 (0)
視神経萎縮	1/3 (33.3)	1/3 (33.3)	未測定	2/2 (100)
緑内障	0/4 (0)	0/4 (0)	未測定	未測定
視神経疾患	2/13 (15.4)	2/13 (15.4)	—	2/9 (22.2)

数字は改善した眼数 / 評価できた眼数(%)
ERG：網膜電図，VEP：視覚誘発電位

Electronics, Inc., Mount Airy, MD, USA)を用いてTES(電流強度400～1,700 μA, 10 msec/phase, 20 Hz, 刺激時間30分)を行った。コンタクト型電極の内側と外側には粘弾性物質(Viscot®, Alcon Japan, 東京, 日本)を塗布した。最初に角膜側(コンタクト型電極の内側の電極)を＋，眼瞼側(コンタクト型電極の外側の電極)を－とした二相性刺激(positive first, **図1**)とし，治療は4週間に1度で，計3度行った。治療前と電気刺激1～3カ月後に視力視野ないし電気生理学的検査を行い，治療前と治療後の検査結果を比較した。

他覚的検査として行った電気生理学的検査はISCEV protocolに準拠した全視野網膜電図(ERG)，多局所ERG，視覚誘発電位(フラッシュおよびパターンVEP)で，緑内障に対しては，Heiderberg Retina Flowmeter(HRF, Heidelberg Engineering, Heidelberg, Germany)を用いて視神経乳頭辺縁部の組織血流を測定した。

視力の変化はlog MAR換算にて0.2以上の変化を改善ないし悪化とし，光覚弁，手動弁，指数弁は平均値計算や変化の評価から除外した。視野検査結果については，ゴールドマン視野(GP)の場合V/4の範囲または絶対暗点の範囲の20%以上の変化を，静的視野検査の場合ハンフリー視野(HFA)のmean deviation値，オクトパス視野のmean defect値の20%以上の変化を改善ないし悪化とした。

❷ 視機能への効果

アカゲザル(n＝2)に対し，TES(電流強度500 μA, 10 msec/phase, 20 Hz, 刺激時間1秒間)を行い，角田らが開発した網膜内因性信号計測法(FRG)[15)～17)]を用いて電気刺激による網膜の神経活動をマッピングした。その結果を光刺激によるFRG記録と比較した。内因性信号とは，神経活動が起こった部分の光反射率が変化する現象を利用して神経活動を測定する方法[18)]であり，角田らが初めて網膜に応用し[16)17)]，網膜神経活動の詳細なマッピングを可能とした。

II. 結　果

各疾患の治療前後の視力変化は**表1**に，まとめとしての自覚的視機能検査(視力と視野)と他覚的視機能検査(ERGとVEP)の変化の割合を**表2**に示す。

❶ 治療としての評価

1)　網膜疾患

①網膜色素変性症

図2に代表症例の視野所見および，全症例の視力・視野変化を示す。視力は幾何平均で治療