〔千葉医学 79：57～64，2003〕

〔Original Paper〕

Assessment of visual function before and after glaucoma surgery by pattern visual evoked cortical potentials

Kazuhide Tsukamoto, Naoya Fujimoto and Emiko Adachi-Usami

(Received November 22, 2002, Accepted December 13, 2002)

SUMMARY

Pattern visual evoked cortical potentials (PVECPs) are sensitive measures of optic nerve disease. In patients with glaucoma, PVECPs reflect central visual function objectively. After performing glaucoma surgery to lower intraocular pressures (IOPs), ophthalmologists should take careful measurements of central visual field postoperatively. We studied visual function with PVECPs and the Humphrey Visual Field Analyzer 30-2 full-threshold program pre- and postoperatively in patients with open angle glaucoma. Fourteen trabeculectomies and 1 trabeculotomy were performed. Only the difference between IOPs before and after surgery was statistically significant; PVECPs and visual fields showed no change. Thus, PVECPs objectively showed the safety of glaucoma surgery on central visual function.

Key words: PVECPs, glaucoma, trabeculectomy, half-field, automated perimetry

Abbreviations: PVECPs: pattern visual evoked cortical potentials
IOP: intraocular pressure
MMC: mitomycin C

I. Introduction

Pattern visual evoked cortical potentials (PVECPs) are known to be sensitive objective measures of optic nerve disease such as optic neuritis. The results depend only on the subjective function of the central part of the visual field. PVECPs reflect especially the central 5 degrees of visual field, even if visual acuity is intact. Damage to the central visual field leads to an increase in P100 latency[1].

In glaucoma, if visual acuity is normal and visual field defects do not extend into the 5 degrees of visual field, PVECPs would be slightly affected but within normal range[2]. An increase in the P100 latency of PVECPs seems to be clinically found only when glaucoma affects the sensitivity of the visual field center[3,4]. Thus, in glaucoma, PVECPs reflect central visual function (visual acuity and visual field) objectively.

Therapy to lower intraocular pressure (IOP)

Department of Ophthalmology and Visual Science, Graduate School of Medicine, Chiba University, Chiba 260-8670.
塚本和秀，藤本尚也，安達惠美子：緑内障手術前後のパターンVECPによる評価.
千葉大学大学院医学研究院視覚病態学 Tel. 043-226-2124.
2002年11月22日受付，2002年12月13日受理.

would be expected to be beneficial in patients who are at risk of glaucoma progression[5,6]. When the IOP is poorly controlled with medical treatment, glaucoma surgery must be considered. However, glaucoma surgery can also affect central visual field and decrease visual acuity postoperatively.

In the present report, PVECPs were recorded before and after IOP-lowering surgery, and visual field was assessed with the central 10 degrees of the Humphrey Visual Field Analyzer 30-2 full- threshold program subjectively.

Ⅱ. Materials and Methods

Written informed consent was obtained from each subject studied.

Fifteen eyes of 15 patients with open angle glaucoma underwent glaucoma surgery at the Department of Ophthalmology, Chiba University Hospital. There were 13 male and 2 female patients between the ages of 11 and 73 years (mean, 58 years). Preoperatively, their visual acuity was 0.7 or better. Each had visual field defects ranging from early stage to moderate stage. Two different surgical techniques which are routinely used at present were performed. Namely, one eye from 14 patients underwent trabeculectomy with adjunctive mitomycin C (MMC), and one eye from one patient (Table; case3) underwent trabeculotomy. All surgeries were performed by the same experienced ophthalmologist. The target IOPs were less than 20mmHg for within -10dB of MD of the Humphrey Visual Field Analyzer 30-2 full-threshold program. Trabeculectomy is a filtering surgery that reduces IOP by creating a new pathway for anterior aqueous humor to enter the subconjunctiva. Using of adjunctive MMC inhibits scar formation in the new pathway. In the present study all trabeculectomies were performed with an adjunctive MMC. After trabeculectomy with MMC, IOPs usually measure in the low teens. The trabeculotomy directly connects Schlemm tube's inner space to the anterior chamber with use of an incision in the trabecular meshwork, which is a highly resistant space of aqueous humor outflow. After trabeculotomy, IOPs usually measure in the high teens.

PVECPs were recorded with the active electrode positioned at Oz and referred to the linked earlobe electrode. Visual stimulus was a black and white checkerboard pattern generated on a television monitor. The check size was 30 minutes of arc. The mean luminance was kept at 39 cd/m^2. The stimulus field of pattern was 11 × 8 degrees. The pattern was reversed at 3 reversals/s for transient PVECPs and 12 reversals/s for steady-state PVECPs.

The subjects fixated on a point in the center of the monitor monocularly from an observing distance of 170 cm, with the same pupil diameter, under full refractive correction.

In transient PVECPs, the latency was measured from the P100 component, and the amplitude was measured from the bottom of a preexisting negative wave around 70 ms to the peak of P100. In steady-state PVECPs, the amplitude was measured from the bottom of a quasi-sinusoidal wave to the peak of the wave, and its ratio was calculated.

The Humphrey Visual Field Analyzer 30-2 full-threshold program, an automated computed program can be used to measure the 76-point threshold distributed 6 degrees within the central 30 degrees by changing luminance of the target. In the present study, we assessed the central 4 points, sum of temporal 2 points/sum of total 4 points, sum of nasal 2 points/sum of total 4 points, and sum of nasal 2 points/sum of temporal 2 points. All data are shown in the Table.

For statistical analysis, a P value less than 0.05 (Wilcoxon signed-rank test) was considered significant.

Table Clinical data measured in study patients.

Case	Eye	age	sex	IOP	V.A.	Vf.MD(-)	Vf (T/F)	Vf (N/F)	Vf (N/T)	P100 latency (ms)	P100 Amp (μV)	StF•Amp (μV)	StT•Amp (μV)	StN•Amp (μV)	St (T/F)	St (N/F)	St (N/T)
1	l	64	m	30/8.0	1.2/0.7	16.69/16.44	0.68/0.64	0.32/0.36	0.47/0.56	102.5/125	7.0/7.0	5.5/9.3	6.8/5.3	2.5/2.5	1.24/0.57	0.45/0.27	0.37/0.47
2	r	67	m	23/13	0.8/0.6	27.39/25.73	1.0 /1.0	0 /0	0 /0	112.5/125	5.5/6.5	5.5/7.0	4.0/3.0	3.0/3.5	0.73/0.43	0.55/0.5	0.75/1.17
3	r	11	f	47/15	1.0/1.2	4.28/1.85	0.49/0.5	0.51/0.5	1.03/1.01	103.8/107.5	5.0/8.3	3.3/7.0	4.5/5.5	5.5/6.5	1.36/0.79	1.67/0.93	1.22/1.18
4	r	72	m	18/13	1.0/0.8	23.04/21.97	0.61/0.55	0.39/0.45	0.65/0.83	125 /130	1.8/4.0	0/0	0/0	0/0	non rec	non rec	non rec
5	r	55	m	31/12.0	1.0/1.2	28.57/28.21	0.66/0.66	0.34/0.34	0.52/0.52	110 /120	4.0/2.8	3.5/3.8	2.3/3.3	3.0/2.8	0.66/0.87	0.86/0.74	1.3 /0.85
6	l	73	m	26/18	0.9/0.9	15.58/18.8	0.72/0.64	0.28/0.36	0.39/0.57	107.5/115	7.5/5.5	7.0/5.5	3.5/5.5	2.5/3.0	0.5 /1.0	0.36/0.55	0.71/0.55
7	r	68	m	28/15	0.7/0.8	28.79/23.08	non/0.47	non/0.53	non/1.11	140 /115	7.3/7.0	3.3/9.5	3.0/5.0	3.0/6.0	0.91/0.53	0.91/0.63	1.0 /1.2
8	r	59	m	28/16	1.0/0.8	17.61/16.21	0.5 /0.5	0.5 /0.5	1.02/1.02	125 /127.5	7.5/9.0	5.0/7.5	6.8/6.3	3.0/4.0	1.36/0.84	0.6 /0.53	0.44/0.63
9	r	48	m	44/17	1.2/1.0	22.35/27.14	0.55/0.61	0.45/0.39	0.81/0.62	non rec	non rec	3.5/2.8	2.5/3.0	2.0/3.3	0.71/1.07	0.57/1.18	0.8 /1.1
10	r	58	m	16/9.0	1.2/0.9	24.46/24.17	0.5 /0.56	0.5 /0.44	1.0 /0.79	100 /107.5	7.5/3.8	6.8/4.0	7.0/4.0	6.5/4.5	1.03/1.0	0.96/1.13	0.93/1.13
11	r	57	m	38/11.0	1.0/1.0	5.26/2.97	0.54/0.49	0.46/0.51	0.86/1.05	97.5/105	3.5/2.3	4.8/4.0	2.8/3.0	3.5/2.8	0.58/0.75	0.73/0.7	1.25/0.93
12	l	44	m	22/16	1.2/0.8	27.54/24.58	1.0 /1.0	0 /0	0 /0	102.5/102.5	2.0/3.5	2.5/4.5	2.5/4.0	3.0/3.8	1.0 /0.89	1.2 /0.84	1.2 /0.95
13	r	70	m	21/13	1.0/0.9	12.01/11.72	0.5 /0.54	0.5 /0.46	1.0 /0.87	115 /110	5.0/3.5	4.0/5.5	3.8/3.8	2.5/2.0	0.95/0.69	0.63/0.36	0.66/0.53
14	r	49	f	47/8.0	1.0/0.6	6.11/2.85	0.48/0.5	0.52/0.5	1.08/1.0	102.5/100	4.5/4.0	10.5/7.0	7.5/6.5	4.5/4.0	0.71/0.93	0.43/0.57	0.6 /0.62
15	l	71	m	27/6.0	0.7/1.0	11.15/12.45	0.49/0.5	0.51/0.5	1.04/1.0	110 /97.5	3.5/7.5	4.0/4.8	2.5/3.0	3.5/4.0	0.63/0.63	0.75/0.84	1.2 /1.33

Each data entry indicates (/) means pre/post. r; right, l; left. m; male, f; female.
Vf; Humphrey Field Analyzer 30-2 full-threshold, MD; mean deviation
Vf (/) means each ratio of central 4 points.
Amp; Amplitude, non rec; non recordable
St; steady-stateVECP, F; full field, T; temporal half-field, N; nasal half-field.
T/F, N/F, N/T means each ratio.

Ⅲ. Results

1. Intraocular pressure

The preoperative IOP was 29.73±10.02mm Hg (mean±SD), and the postoperative IOP was 12.67±3.64 mmHg; the difference was statistically significant (P=0.0007).

2. Visual acuity

The preoperative visual acuity was 0.99±0.17, and the postoperative visual acuity was 0.88±0.18; the difference was not statistically significant (P=0.0966). Nine of the 15 eyes (60%) showed deterioration. No eye was less than or equal to 0.6 postoperatively (Fig.1a).

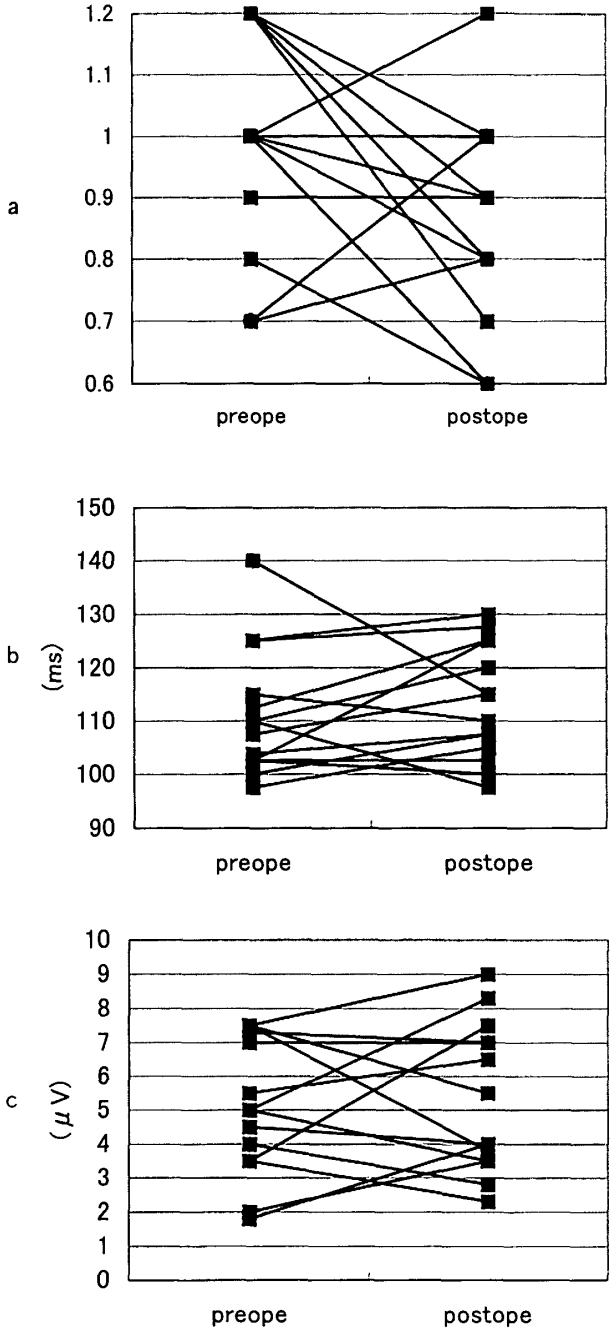

Fig. 1 Visual acuity change (a) and transient PVECP change (b,c).
Shown are the (b) P100 latency of the transient PVECP and the (c) P100 amplitude of the transient PVECP.

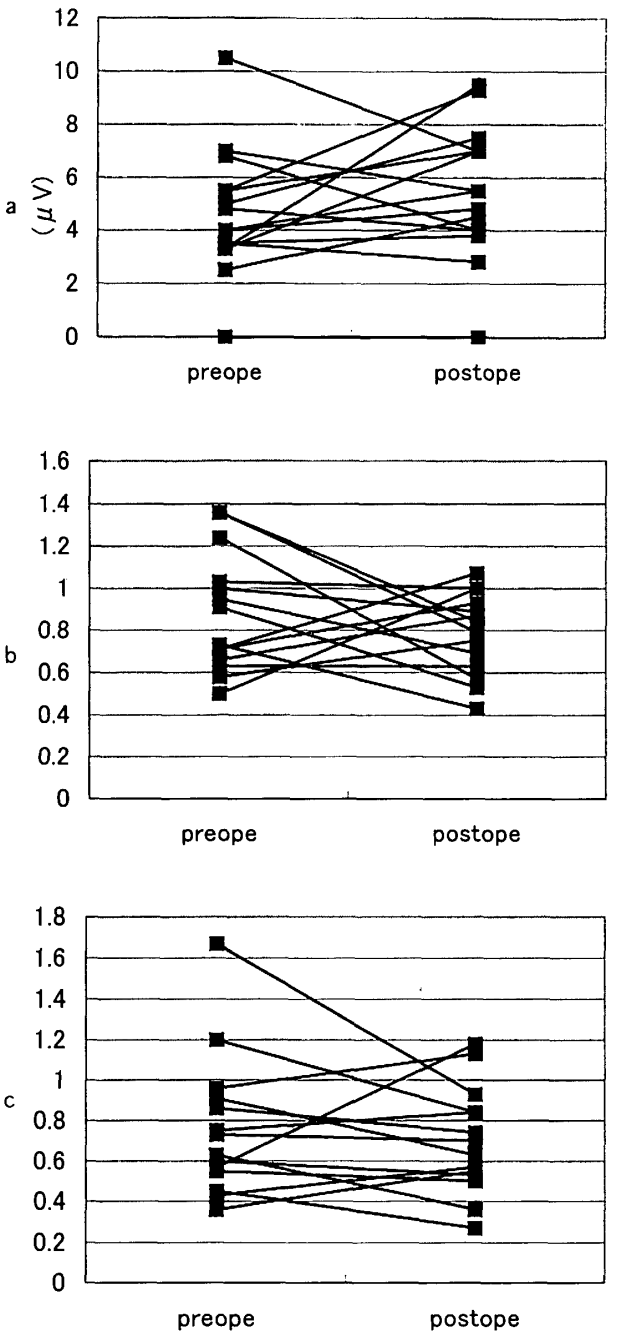

Fig. 2 Steady-state PVECP change.
Shown are the (a) amplitude of full field; (b) in ratio of amplitude, temporal half-field/full field; and (c) in ratio of amplitude, nasal half-field/full field.

3. Visual field

Mean deviation (MD) means diffuse loss of visual field. The preoperative MD was −18.06 ± 8.77dB, and the postoperative MD was −17.21±9.08dB. Postoperative MD improved slightly, but the difference was not statistically significant (P=0.1117); neither was the central 4 point's ratio. There was loss of value (case 7) because the sum of 4 points was 0 preoperatively.

4. PVECPs

(1) transient PVECPs

The preoperative P100 latency was 111.0± 11.9ms, and the postoperative P100 latency was 113.4±10.7ms ; the difference was not statistically significant (P=0.2625). Nine of the 14 eyes (64.3%) showed prolongation (Fig.1b). P100 amplitude did not change, and the difference was not statistically significant (Fig.1c). Case 9 showed no recordable transient PVECPs pre- and postoperatively.

(2) Steady-state PVECPs

Each amplitude of full field increased in 9 of the 15 eyes (60%), but the difference was not statistically significant (P=0.2087) (Fig.2a), and neither was that of temporal and nasal half-fields. In ratio of amplitude, temporal half-field/full field and nasal half-field/full field showed slightly lowering, but the difference was not statistically significant (Fig.2 b,c), and the nasal half-field/temporal half-field did not change. Case 4 showed no recordable steady-state PVECPs pre- and postoperatively. Examples of recordings in healthy subjects are shown in Fig.3.

IV. Discussion

Although rare, glaucoma filtration surgery can result in visual acuity loss by a variety of mechanisms such as lens opacification (cataract), persistent hypotony, and loss of central vision (wipe out)[7,8]. Wipe out is especially known to cause severe complications, and older patients with advanced visual field defects are

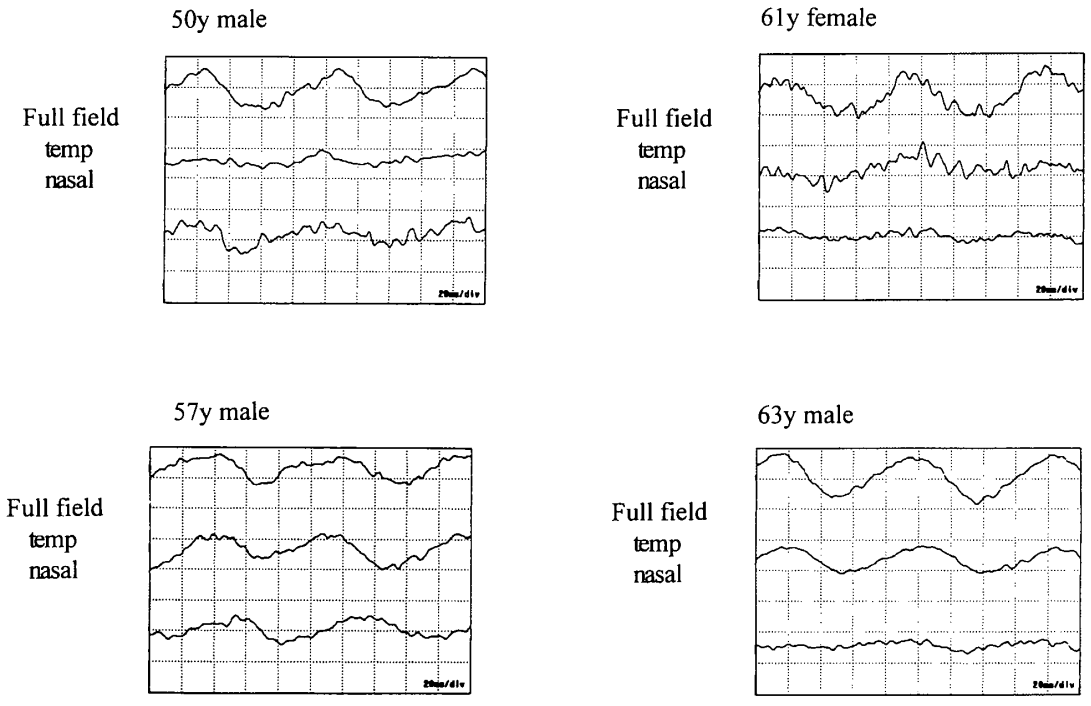

Fig. 3 Examples of steady-state PVECP recordings in four healthy subjects.

at increased risk[7]. In the present study, no patient showed a postoperative complication (cataract, persistent hypotony, wipe out, etc.) in 15 of 15 eyes, but slight deterioration of visual acuity was found.

In visual field change after IOP reduction, mean deviation and pattern standard deviation of the Humphrey Field Analyzer 24-2 full-threshold program improves in early-to-moderate chronic open angle glaucoma[9]. Also, mean sensitivity improves, but corrected loss variance does not improve the G1 program of the Octopus perimeter[10]. Those results indicate that diffuse loss of visual field improves after glaucoma surgery.

Many reports suggest that reducing the IOP may improve visual function to some extent in the short term. Surgical reduction of IOP helps in preventing the progression of visual field damage in open angle glaucoma[5], in normal tension glaucoma[6], and in high IOPs of normal tension glaucoma[11]. In the present study, we examined the nasal field changes of the Humphrey Field Analyzer 30-2 full-threshold program using the central 4 points and, in most cases, detected glaucomatous visual field damage that did not subsequently improve.

PVECPs have been shown to be sensitive to optic nerve disease such as optic neuritis[12], depending only on the function of the central part of the visual field. PVECPs are also used to monitor glaucoma treatment. The central visual function is often assessed in glaucoma by P100 latency in PVECPs[3-4,13]. It is apparent that the P100 latency could reveal central visual dysfunction in glaucoma and central sensitivity with Octopus perimetry[3-4].

In our patients, the P100 latency of transient PVECPs and the amplitude of steady-state PVECPs did not change in most cases. Distinct improvement was found only in case 7. This was the only patient who improved subjectively, and the PVECPs could reveal the recovery. P100 latency of transient PVECPs does not usually recover after trabeculectomy in cases of POAG[14].

Prolongation of P100 latency was slight in many cases, but it was not statistically significant. Subjects with early-moderate glaucoma demonstrated some deterioration after trabeculectomy, but it did not affect P100 latency.

Steady-state PVECPs may be more sensitive than transient PVECPs in optic neuritis[15]. They have been used for quarter-field and half-field responses. Half-field responses, are upper and lower half-field responses and temporal and nasal half-field responses. In upper and lower half-field responses, phase differences between the lower and upper hemifield responses often result in phase reversal. The response amplitude is greater for lower than upper field stimuli[16, 17].

To assess spatial frequency, characteristics in the upper and lower hemiretina using PVECPs suggest that the spatial frequency characteristics between the upper and lower hemiretina are different[18]. Many studies of diseases from the optic chiasm to the visual cortex describe temporal and nasal half-field responses[19,20]. In quadrant responses, no significant difference is found in the phase of responses from normal homonymous quadrants. In patients with ocular hypertension and glaucoma, progressive visual field does not show recordable PVECPs or a phase shift. Responses are conducted by surviving nerve fiber groups around nonfunctioning areas, and the nature of the signals appears to depend on the ratio of normal to damaged fiber groups. Also, an absolute scotoma occupying a relatively small proportion of a quadrant may be associated with a high percentage of abnormally functioning fiber groups, with the production of a delayed response on stimulation of the quadrant[21].

Because phase reversals in the half-field responses are found in many cases, even in normal individuals due to changing the position of the electrode, it might be unreliable to assess visual field damage only by phase shift[16,17].

In the present study, we compared nasal field responses to show damage in eyes with glaucoma through temporal field responses. The difference in individual variations of steady-state PVECPs amplitude was not statistically significant.

Thus, PVECPs objectively showed that central visual function was preserved after glaucoma surgery.

Acknowledgement

The editing assistance of Ms. Maxine Gere is gratefully acknowledged.

要　旨

パターン視覚誘発電位（PVECP）は視神経炎を始めとする視神経疾患への適応が広く知られており，網膜から視中枢までを反映する電気生理的検査である。視力良好眼であっても特に中心10°以内の影響を受け，その障害はP100成分の頂点潜時延長をきたす。緑内障においては視力良好で10°以内に暗点がなければ，そのPVECPは正常範囲内となることが多い。中心の固視点が障害されるとP100頂点潜時延長をきたす。以上より緑内障においてもPVECPは中心部視機能（視力，視野）を他覚的に反映することがわかっている。緑内障においては眼圧下降させることが，視野障害進行を抑制する唯一の手段であり，薬物でコントロール不良な場合，手術を考慮せざる得ない。しかし緑内障手術は眼圧を下降させるが，術後中心視野への影響も懸念される。今回我々は緑内障手術前後でPVECPを記録し，自覚的検査には自動視野計ハンフリー視野の閾値検査の中心10°以内を検討した。

術式は線維柱帯切除術14眼，線維柱帯切開術1眼，前者ではマイトマイシンCを全例使用している。比較はウィルコクソン符号付順位検定で行った。

結果は眼圧下降を除いて，PVECP・視野共に統計的有意差は認められなかった。

このことは緑内障手術後に自覚的な視野，他覚的なPVECPとも視機能を維持し，手術の安全性を支持すると考えられた。

References

1) Fujimoto N, Adachi-Usami E. Evaluation of the central visual field measured by automated perimeter Octopus and pattern VECP in optic neuritis. Nippon Ganka Gakkai Zassi (Acta Soc Ophthalmol Jpn) 1987; 91: 951-5.
2) Bartl G. The effects of visual field changes and ocular hypertension on the visual evoked potential. Ann N Y Acad Sci 1982; 388: 227-42.
3) Huber C. Pattern evoked cortical potentials and automated perimetry in chronic glaucoma. Doc Ophthalmol Proc Ser 1981; 27: 87-94.
4) Fujimoto N, Adachi-Usami E. Evaluation of the central visual function in glaucoma measured by automated perimeter Octopus and pattern VECP. Nippon Ganka Gakkai Zassi (Acta Soc Ophthalmol Jpn) 1988; 92: 682-6.
5) The AGIS Investigators. The Advanced Glaucoma Intervention Study (AGIS): 7. The relationship between control of intraocular pressure and visual field deterioration. Am J Ophthalmol 2000; 130: 429-40.
6) The Collaborative Normal-Tension Glaucoma Study Group. The effectiveness of intraocular pressure reduction in the treatment of normal-tension glaucoma. Am J Ophthalmol 1998; 126: 498-505.
7) Costa VP, Smith M, Spaeth GL, Gandham S, Markovitz B. Loss of visual acuity after trabeculectomy. Ophthalmology 1993; 100: 599-612.
8) Mizoguchi T. Visual acuity after glaucoma surgery. Jpn J Ophthalmic Surg 1997; 10: 327-33.
9) Tsai CS, Shin DH, Wan JY, Zeiter JH. Visual field global indices in patients with reversal of glaucomatous cupping after intraocular pressure reduction. Ophthalmology 1991; 98: 1412-9.
10) Gandolfi SA. Improvement of visual field indices after surgical reduction of intraocular pressure. Ophthalmic Surg 1995; 26: 121-6.
11) Daugeliene L, Yamamoto T, Kitazawa Y. Effect of trabeculectomy on visual field in progressive normal-tension glaucoma. Jpn J Ophthalmol 1998; 42: 286-92.
12) Fujimoto N, Adachi-Usami E. Clinical evaluation of P100 peak latency of pattern visually evoked cortical potentials. Rinsho Ganka (Jpn J Clin Ophthalmol) 1997; 51: 1671-4.
13) Towele VL, Moskowitz A, Sokol S, Schwartz B. The visual evoked potential in glaucoma and ocular hypertension: Effects of check size, field size, and stimulation rate. Invest Ophthalmol Vis Sci 1983; 24: 175-83.
14) Spadea L, Giuffre I, Bianco G, Balestrazzi E. PERG and P-VEP after surgical trabeculec-

tomy in primary open-angle glaucoma. Eur J Ophthalmol 1995; 5: 92-5.
15) Takasoh M, Adachi-Usami E, Mizota A. Steady-state PVECP is superior to transient PVECP in the diagnosis of optic neuritis. Acta Ophthalmol 1998; 76: 230-3.
16) Adachi-Usami E, Chiba J, Yanasima K. The effect of temporal frequency changes on human pattern VECPs in response to upper and lower half field stimulation. Doc Ophthalmol Proc Ser 1981; 27: 367-74.
17) Adachi-Usami E. Visual checkerboard-evoked potentials from upper and lower retinal halves, and variation of check size. Neuroscience Letters 1981; 22: 245-50.
18) Sano N, Adachi-Usami E. Decreased contrast sensitivity in normal tension glaucoma determined by pattern visually evoked cortical potentials. Clin Neurosci 1997; 4: 292-4.
19) Milner BA, Regan D, Heron JR. Theoretical models of the generation of steady-state evoked potentials,their relation to neuroanatomy and their relevance to certain clinical problems. Adv Exp Med Biol 1972; 24: 157-69.
20) Blumhardt LD, Barrett G, Halliday AM. The asymmetrical visual evoked potential to pattern reversal in one half field and its significance for the analysis of visual field defects. Br J Ophthalmol 1977; 61: 454-61.
21) Cappin JM, Nissim S. Visual evoked responses in the assessment of field defects in glaucoma. Arch Ophthalmol 1975; 93: 9-18.