Yonago Acta medica 2005;48:83–92

Effects of Metoclopramide Hydrochloride, a D_2-Selective Dopamine Receptor Antagonist, on the Fast Oscillation of the Electrooculogram

Norio Miki*, Hiroshi Nakao†, Jiro Hasegawa, Takashi Baba, Ryoko Ishikura, Akiko Kakimaru, Keiko Sakatani, Atsushi Yamasaki, Yuji Sasaki and Akihiko Tamai‡

*Division of Ophthalmology and Visual Science, Department of Medicine of Sensory and Motor Organs, School of Medicine, Tottori University Faculty of Medicine, Yonago 683-8504, *Clinic of Ophthalmology, Miki Eye Clinic, Tottori 680-0801, †Clinic of Ophthalmology, Nakao Eye Clinic, Nishiwaki 677-0021 and ‡Clinic of Ophthalmology, Hino Hospital Association Hino Hospital, Hino 689-4504 Japan*

Fast oscillation (FO) of an electrooculogram (EOG) was recorded in both eyes of 10 healthy volunteers before and after administration of metoclopramide hydrochloride (MTCL), a D_2-selective dopamine receptor antagonist, paying particular attention to sex concerning sensitivity to dopamine in young subjects. Healthy volunteers were divided into male and female groups; 5 males (10 eyes) aged 21 to 23 years (average, 21.8 years) and 5 females (10 eyes) aged 19 to 25 years (average, 21.8 years). As an FO parameter, the df_{FO} (the averaged difference in μV between maximum amplitude in the dark period and minimum amplitude in the light period during FO measurement) was evaluated. The mean level of df_{FO} significantly increased between phase A (the initial 10 min before intravenous injection of 10 mg of MTCL) and phase B (10 min after the injection) in the male and female groups ($P < 0.01$ and $P < 0.025$) and between phase A and phase C (the additional 10 min after the injection) in both groups ($P < 0.01$ and $P < 0.05$). The mean level of df_{FO} in the female group was significantly higher than that of the male group in phase B ($P < 0.05$). As a control, the experimental procedure was performed with physiological saline administration, and no changes were observed. The data suggest that there exists some difference between young males and females generation concerning sensitivity to dopamine and that young females may show a higher-than-male sensitivity to dopamine in the occurrence of FO potential.

Key words: D_2-selective dopamine receptor antagonist; dopamine; electrooculogram; fast oscillation; metoclopramide hydrochloride

Fast oscillation (FO) of the electrooculogram (EOG) is the rapid initial deflection of opposite polarities occurring at the initial stage of the light and dark periods in the EOG procedure (Kolder and Brecher, 1966; Kolder, 1974). That is, FO shows a peak in the dark adaptation (dark peak) and a trough in the light adaptation (light trough) in response to dark and light periods of approximately 1.1 min each. FO is distinct from ordinary slow oscillation (SO) of the EOG which shows a

Abbreviations: df_{FO}, averaged difference in μV between maximum amplitude in the dark period and minimum amplitude in the light period during FO measurement; EOG, electrooculogram; FO, fast oscillation; MTCL, metoclopramide hydrochloride; SO, slow oscillation

trough in the dark adaptation (dark trough) and a peak in the light adaptation (light peak) in response to dark and light periods of approximately 12.5 min each (Kolder and Brecher, 1966; Kolder, 1974; Welber, 1989).

Concerning the origin and occurrence of FO and SO, Steinberg and others (1983) reported the involvement of the retinal pigment epithelium, mainly its basal membrane in the FO potential, while Arden and others (1962) reported the involvement of the retinal pigment epithelium and photoreceptor complex in the SO potential.

Joseph and Miller (1991) suggested that the downward oscillation of FO might result from a delayed hyperpolarization associated with increased electric resistance of the basal membrane of the retinal pigment epithelium. The delayed hyperpolarization is thought to be caused by a decrease in intracellular chloride, which is linked to the light-induced drop in subretinal potassium concentration (Joseph and Miller, 1991). The upward oscillation of FO is thought to result from a depolarized change associated with decreased electric resistance of the basal membrane of the retinal pigment epithelium. This depolarized condition of the basal membrane may be caused by an increase in intracellular chloride of the retinal pigment epithelium, which is linked to the dark-induced recovery in subretinal potassium concentration (Nikara et al., 1974).

On the other hand, dopamine, a retinal neurotransmitter, has been known to be indispensable for the process of generation and delivery of electric excitement in the ordinary SO potential (Dawis and Niemyer, 1986; Jaffe et al., 1987; Gallemore et al., 1988; Maruiwa et al., 1992). According to the results of an experiment in a report by Maruiwa and others (1992), metoclopramide hydrochloride (MTCL), a D_2-selective dopamine receptor antagonist (Schulze-Delrieu, 1979), which was given intravenously in 5 healthy volunteers aged 23 to 33 years, increased the dark-adapted SO amplitudes transiently and suppressed the light-adapted SO amplitudes.

However, little has been known of the reaction and influence of dopamine on the FO potential. In this report, we have tested the effects of MTCL on FO in 10 healthy volunteers aged 19 to 25 years, paying particular attention to the existence of difference in sex concerning sensitivity to dopamine in young subjects, since Nakao and others (1994) postulated the possibility in their experiment, in which fluctuations in the FO potential obtained from female normal subjects averaging 22.7 years of age were relatively larger than those from normal male subjects averaging 24.3 years of age.

Subjects and Methods

Subjects

In this study, 10 healthy volunteers aged 19 to 25 years with normal, functional eyes (20 eyes), in whom error of refraction did not exceed ± 3 diopters, were tested at the Department of Ophthalmology, Tottori University Hospital. The healthy volunteers were divided into male and female groups; 5 males (10 eyes) aged 21 to 23 years (average, 21.8 years) and 5 females (10 eyes) aged 19 to 25 years (average, 21.8 years).

Before the trial, the purpose of the experiment and the tasks to be performed were fully explained to each volunteer, and written consent was obtained. All procedures conformed to the tenets of the Helsinki Declaration.

Apparatus and methods for FO recording

Using a newly devised automated electrooculograph, a Nidek EOG-2 (Nidek, Gamagori, Japan) (Nakao et al., 1994; Inoue et al., 2003; Tamai et al., 2004), FO was recorded in each subject. The EOG-2 consists of a dome, a personal computer, an index controller, an amplifier, a printer and an EOG pen recorder. Inside the dome is a hemispheric screen with a radius of 300 mm. Four tungsten lamps (115 V, 50 W each) produce a background luminance of 1,270 lux when measured at the location of the subject's eyes. In this study, the background light was periodically

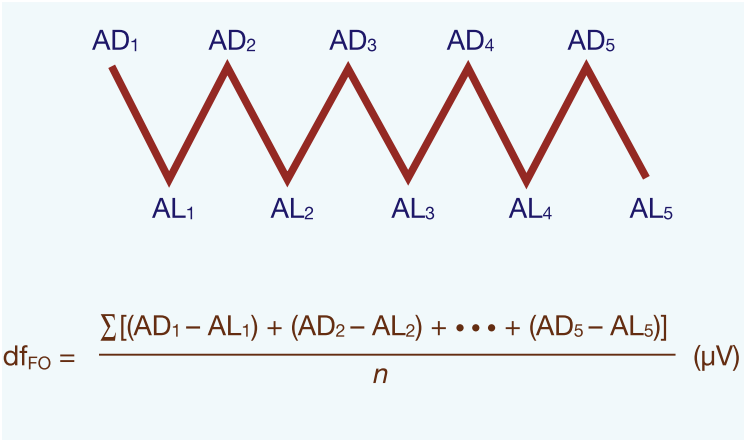

Fig. 1. Calculation method for df_{FO} as an FO parameter in this survey. AD, maximum amplitude in the dark period; AL, minimum amplitude in the light period during FO measurement. *n*, number of pairs (alternating dark-light period of 1 min each), 5 pairs in total. df_{FO} was calculated only if at least 3 successive pairs were observed ($5 \geq n \geq 3$).

turned on and off at intervals of 1 min with the aid of the computer.

For every subject, cup-shaped silver-silver chloride conductive electrodes, 8 mm in diameter, were placed beside both canthi of each eye on the orbital margin, and a grounding electrode with the same cup shape was placed on the left earlobe, as routinely used. Before setting these electrodes, the skin was cleaned with 90% alcohol, and then the electrodes were applied with a conductive paste. Electrode resistance was below 10 kΩ. Under these conditions, simultaneous recording of the FO potentials from each eye of every subject was possible.

Mydriasis can provide better control of retinal illumination. However, FO recording was performed without mydriasis, because mydriasis may increase discomfort in subjects. Before the FO recording, a 10-min pre-light adaptation period at a background luminance level of 1,270 lux was given. Then the subjects were introduced to fixate alternately on a pair of targets on the screen inside the dome. The two targets subtended 40˚ to the visual angle were presented alternately with a frequency of 0.5 Hz.

After this adaptation period, the dome was periodically illuminated for 1 min followed by 1 min of darkness for 30 min. The FO potentials showed peaks in darkness and troughs in light near the end of the dark and light periods respectively; that is, between 45 s and 55 s after the start of each period (De Rouck and Kayembe, 1981). Therefore, the FO measurements were performed at 40 to 60 s in each dark and light period; there were 10 measurements in each period. Six out of 10 EOG amplitudes were automatically averaged and recorded at the end of each period through the EOG artifact rejection system on the Nidek EOG-2 (Inoue et al., 2003; Tamai et al., 2004). In this study, the calibration sensitivity for the pen recorder was 200 μV/division on the printer. The time constant of the amplifier was set at 3 s, and a high frequency cutoff of –3 dB was set at 20 Hz.

Administered agent and control solution

After the initial 10 min of alternating dark and light periods (phase A), 10 mg of MTCL in 2 mL of Primperan injection (Fujisawa Pharmaceutical Co. Ltd., Osaka, Japan) was given intravenously from the median cubital vein of each subject in less than 10 s. FO was further recorded for another 20 min (phases B and C, 10 min each, respectively). For the nonchemical control, each subject was asked to receive another set of examinations with an intravenous injection of 2 mL of physiological saline. The control examination was scheduled after an interval of at least 2 weeks.

FO parameter

As an FO parameter, df_{FO}, which is the averaged difference in μV between maximum amplitude in the dark period and minimum amplitude in the light period during FO measurement (De Rouck and Kayembe, 1981; Nakao et al., 2003; Tamai et al., 2004) (Fig. 1), was evaluated. In the present study, each phase showed 5 dark-rise and light-fall

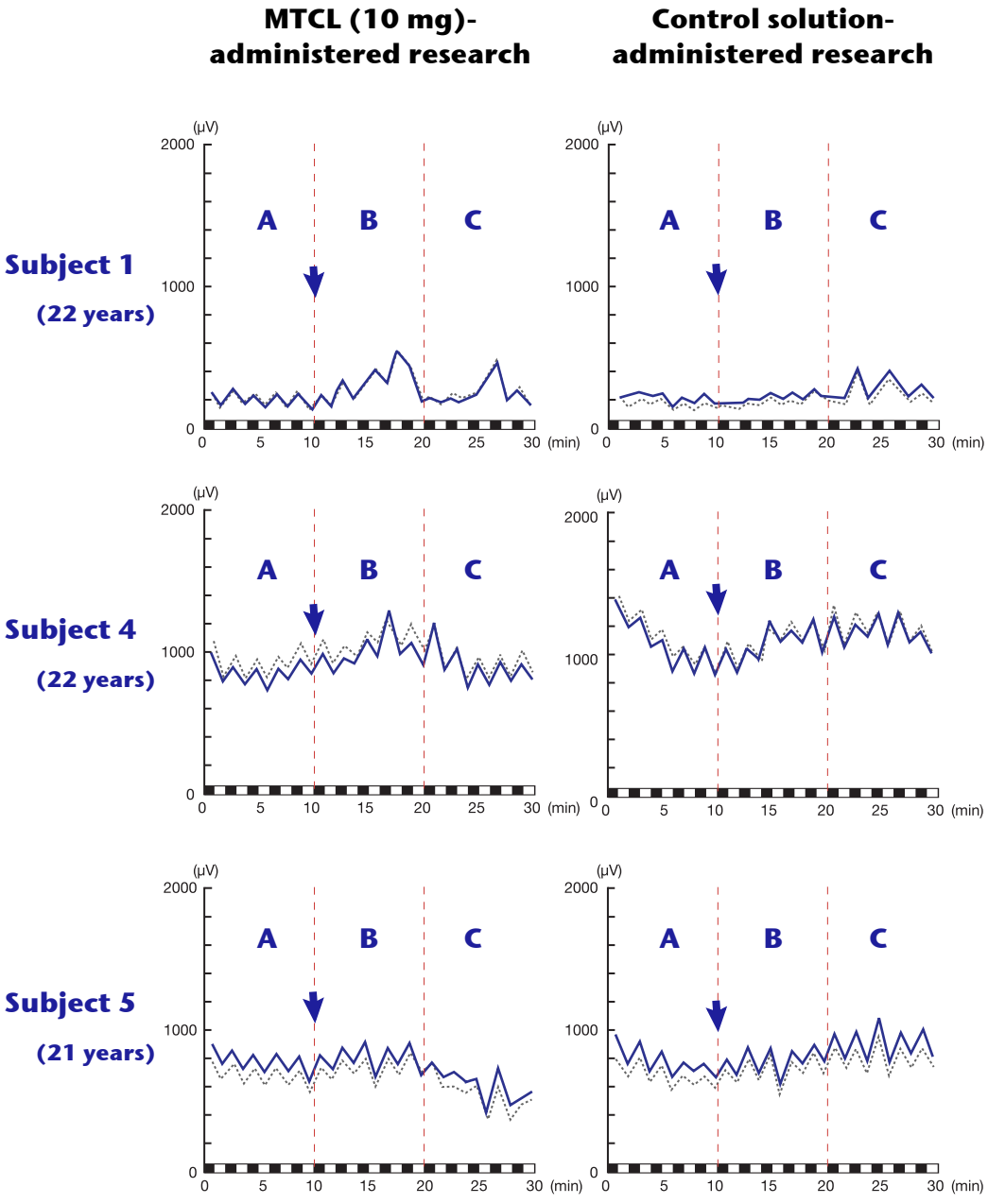

Fig. 2. Some samples of FO patterns of 5 male test subjects. The dotted line in each sample shows FO pattern in the right eye and the solid line shows that in the left eye. Control solution: physiological saline. A, phase A: initial 10 min before intravenous injection; B, phase B: following 10 min after the injection; C, phase C: additional 10 min after the injection. A dark arrow in each sample indicates the injection point. ■, dark period; □, light period (horizontal axis).

zigzag FO patterns (5 pairs of FO measurements), according to the alternating dark-light period of 1 min each. df_{FO} was calculated only if at least 3 successive pairs were observed (Fig. 1). Isolated and occasional FO patterns were not taken into account.

Statistical analysis

All values were expressed as mean ± SD. Statistical analysis was performed with Wilcoxon's rank sum test of correspondence or non-correspondence. Values of $P < 0.05$ were considered significant.

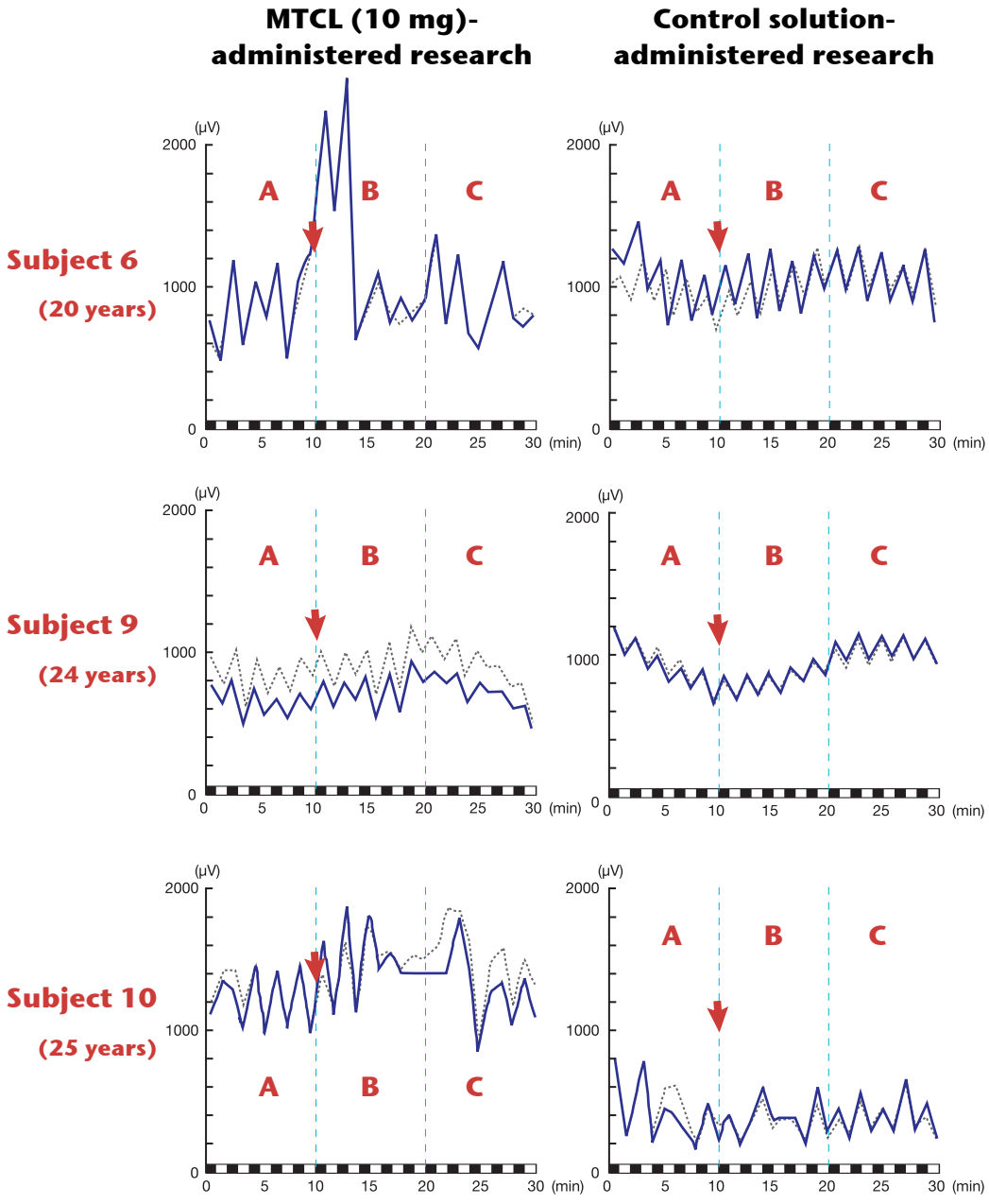

Fig. 3. Some samples of FO patterns of 5 female test subjects. The dotted line in each sample shows FO pattern in the right eye and the solid line shows that in the left eye. Control solution: physiological saline. A, phase A: initial 10 min before intravenous injection; B, phase B: following 10 min after the injection; C, phase C: additional 10 min after the injection. A dark arrow in each sample indicates the injection point. ■, dark period; □, light period (horizontal axis).

Results

Figures 2 and 3 demonstrate some samples of FO patterns obtained in the MTCL (10 mg)- and control solution-administered researches in the male and female test subjects, respectively. After administration of MTCL, markedly fluctuated FO patterns were observed in both eyes of each subject in both groups, especially in the female group in phases B and C after administration, compared with their FO patterns in phase A before administration.

Table 1. The df_{FO} results obtained in the MTCL (10 mg)- and control solution-administered researches in 10 eyes of 5 male healthy volunteers

Subject Number	Age (year)	Measured eye	MTCL (10 mg)-administered research (μV) Phase A	Phase B	Phase C	Control solution-administered research (μV) Phase A	Phase B	Phase C
1	22	Right	126.1	170.4	127.0	46.1	49.2	146.3
		Left	116.5	170.4	104.3	46.9	60.9	178.3
2	21	Right	208.4	224.0	396.0	276.4	197.0	171.2
		Left	238.8	253.5	421.0	320.6	257.4	210.8
3	23	Right	123.4	183.0	175.0	120.2	150.2	130.0
		Left	147.6	197.4	169.0	144.8	145.8	161.4
4	22	Right	173.9	172.1	213.7	178.3	158.2	211.3
		Left	165.2	181.0	228.4	218.3	175.7	193.9
5	21	Right	133.9	193.5	185.5	122.6	157.4	167.8
		Left	159.1	175.7	184.8	160.0	190.4	206.1
Mean			159.3	192.1	220.5	163.4	154.2	177.7
SD			39.4	27.0	105.7	89.4	61.6	27.8
Statistical analysis (Wilcoxon's rank sum test)			$P < 0.01$	NS		NS	NS	
			$P < 0.01$			NS		
NS, not significant ($P > 0.05$)			NS					

Control solution: physiological saline.
Phase A: initial 10 min before intravenous injection. Phase B: following 10 min after the injection. Phase C: additional 10 min after the injection.

Table 2. The dfFO results obtained in the MTCL (10 mg)- and control solution-administered researches in 10 eyes of 5 female healthy volunteers

Subject Number	Age (year)	Measured eye	MTCL (10 mg)-administered research (μV) Phase A	Phase B	Phase C	Control solution-administered research (μV) Phase A	Phase B	Phase C
6	20	Right	391.8	1235.5	539.7	308.0	269.2	314.8
		Left	453.0	1203.5	499.0	345.6	363.4	352.8
7	19	Right	60.4	79.3	100.3	28.4	79.0	86.2
		Left	64.0	61.0	79.0	36.8	58.2	88.4
8	21	Right	156.4	150.0	250.5	110.4	223.0	69.0
		Left	120.6	152.0	266.0	149.8	178.4	99.0
9	24	Right	219.2	267.6	186.2	198.0	137.6	160.8
		Left	189.6	186.2	146.2	188.2	127.8	156.4
10	25	Right	259.0	293.0	274.3	246.6	162.5	193.2
		Left	271.4	522.3	314.0	289.0	261.0	233.8
Mean			210.3	443.8	265.5	190.1	186.0	175.4
SD			130.2	415.0	154.5	109.9	94.0	98.8
Statistical analysis (Wilcoxon's rank sum test)			$P < 0.025$	NS		NS	NS	
			$P < 0.05$			NS		
NS, not significant ($P > 0.05$)			NS					

Control solution: physiological saline.
Phase A: initial 10 min before intravenous injection. Phase B: following 10 min after the injection. Phase C: additional 10 min after the injection.

Table 3. Comparison of the df_{FO} values obtained in the MTCL (10 mg)- and control solution-administered researches in the male and female groups (10 eyes of 5 healthy volunteers each)

Research	Statistical analysis†	Male group (μV)			Female group (μV)		
		Phase A	Phase B	Phase C	Phase A	Phase B	Phase C
MTCL (10 mg)-administered	Mean	159.3	192.1	220.5	210.3	443.8	265.5
	SD	39.4	27.0	105.7	130.2	415.0	154.5
		NS					
			$P < 0.05$				
				NS			
Control solution-administered	Mean	163.4	154.2	177.7	190.1	186.0	175.4
	SD	89.4	61.6	27.8	109.9	94.0	98.8
		NS					
			NS				
				NS			

† Wilcoxon's rank sum test: NS, not significant ($P > 0.05$).
Control solution: physiological saline.
Phase A: initial 10 min before intravenous injection. Phase B: following 10 min after the injection. Phase C: additional 10 min after the injection.

It is of note that a 20-year-old female (Subject 6) showed a highly fluctuated FO pattern associated with increased FO potential after administration of MTCL in phase B, though no remarkable changes were observed in her FO pattern after administration of the physiological saline control solution in phase B (Fig. 3).

Main examination

df_{FO} results obtained in the male and female groups

After administration of MTCL, the mean level of df_{FO} significantly increased between phase A and phase B in the male and female groups ($P < 0.01$ and $P < 0.025$) and between phase A and phase C in both groups ($P < 0.01$ and $P < 0.05$), though no statistically significant differences ($P > 0.05$) were detected in the mean level of df_{FO} between phase B and phase C in either the male or female group (Tables 1 and 2).

Comparison of df_{FO} values between the 2 groups

In comparing the df_{FO} values between the two groups, the mean level of df_{FO} of the 10 eyes of the 5 female test subjects was significantly higher than that of the 10 eyes of the 5 male test subjects in phase B ($P < 0.05$), though no statistically significant differences ($P > 0.05$) were detected in the mean level of df_{FO} in phase A or phase C in MTCL (10 mg)-administration (Table 3).

Control examination

The control examination using physiological saline was performed at least 2 weeks after the main examination. No statistically significant differences ($P > 0.05$) were detected in the mean levels of df_{FO} in either the male or female group in the comparison of the df_{FO} values in phase A between control solution-administration and MTCL (10 mg)-administration (Tables 1 and 2), though relatively larger fluctuations in FO potential were apparently observed in the female sample cases than in the male ones (Figs. 2 and 3).

After administration of the control solution, no statistically significant differences ($P > 0.05$) were detected in the mean level of df_{FO} in either the male or female group throughout the experiment (Tables 1 and 2), even in the comparison of the df_{FO} values between the two groups (Table 3).

Discussion

In the present study, the measuring time of 30 min was tentatively divided into 3 phases (A, B and C) of 10 min each, and the results obtained from each phase were compared with one another, to minimize the influence of SO on FO (Kolder and Brecher, 1965; Kolder, 1974; Nikara et al., 1974; De Rouck and Kayembe, 1981; Thaler et al., 1982; Welber, 1989) and to reflect on reaction time after MTCL administration (Schulze-Delrieu, 1979; Maruiwa et al., 1992).

The ratio of the osmotic pressure from Primperan injection which was adopted in the present survey is approximately 1.0 to physiological saline used as a control solution. Thus it is difficult to imagine that the osmotic pressure in the blood might influence the FO potential (Kawasaki et al., 1977; Dawis et al., 1985; Shirao et al., 1987). Though the pH of this injection is relatively low (2.5 to 4.5), it may be presumed that the pH in the blood would scarcely change after administration of this agent due to the small amount in the injection (2 mL) and buffer reaction in the blood, evoking no influences on the FO potential as well as in the SO potential (Maruiwa et al., 1992).

The agent's permeation into the intraocular portion is unclear, but MTCL passes through the blood-brain barrier (Schulze-Delrieu, 1979; Maruiwa et al., 1992). Thus it is thought that its permeation into the retinal side may be brought about through the blood-retinal barrier.

In the present study, the mean value of df_{FO} significantly increased between phase A (the initial 10 min before intravenous injection of 10 mg of MTCL) and phase B (the 10 min after injection) in the male and female groups ($P < 0.01$ and $P < 0.025$) and between phase A and phase C (the additional 10 min after injection) in both groups ($P < 0.01$ and $P < 0.05$) (Tables 1 and 2). This indicates that the effects of the dopamine receptor blocker on the FO potential were longer than expected.

It is widely accepted that the retinal neurotransmitter dopamine interacts with two major types of dopamine receptors: the D_1 and D_2 dopamine receptors (Kebabian and Calne, 1979). Each receptor has its own agonists and antagonists (Kebabian and Calne, 1979; Dubocovich and Weiner, 1985; Tran and Dickman, 1992).

In the mammalian retina, the D_1 dopamine receptors are mostly concentrated in the inner plexiform, the inner nuclear and ganglion cell layers; they are scarcely present in the outer nuclear layer or the photoreceptor inner and outer segments, while the D_2 dopamine receptors are present in the outer retinal layers—the rods, cones and the retinal pigment epithelium (Dearry and Brunside, 1988; Gallmore and Steinberg, 1990; Tran and Dickman, 1992).

The D_1 dopamine receptors are linked to the stimulation of adenylate cyclase and increase cAMP, whereas the D_2 dopamine receptors are coupled negatively to adenylate cyclase and decrease cAMP. That is, the D_1 and D_2 dopamine receptors are localized differentially in the retina to mediate different physiologic effects of dopamine (Tran and Dickman, 1992).

Thus it is supposed that a blockade of dopaminergic D_2 autoreceptor by MTCL may accelerate the release of endogenous dopamine from the inner retinal layers through negative feedback (Dubocovich and Weiner, 1985; Maruiwa et al., 1992; Tran and Dickman, 1992). Some endogenous dopamine would reach to the outer retinal layers by diffusion or through inter-plexiform cells in the retina (Nguyen-Legros et al., 1989; Tran and Dickman, 1992), and bring about a hyperpolarized change in the basal membrane of the retinal pigment epithelium associated with increased electric resistance of the basal membrane. At the same time, hyperpolaric response of visual cells to light stimuli suppressed by MTCL (Maruiwa et al., 1992) would bring about the decrease of sensitivity of visual cells to light stimulation, resulting in irregularly fluctuated FO patterns associated with increased FO potential and increase of the df_{FO} values in MTCL (10

mg)-administration in the present survey. However, it is thought that direct erethism by released endogeneous dopamine is a rare possibility in the retinal pigment epithelium.

Accordingly, it may be presumed that such a dopaminergic reaction in the outer retinal layers, especially in the retinal pigment epithelium which was observed in the present FO study, may be brought about by a direct effect of MTCL on the D_2 dopamine receptors in the retinal pigment epithelium even in man.

In the main examination, the mean level of df_{FO} of the female group was significantly higher than that of the male group in phase B ($P < 0.05$) (Table 3). As a control, the experimental procedure was performed with physiological saline administration, and no changes were observed. The data suggest that there exists some difference between young males and females concerning sensitivity to dopamine, as previously postulated by Nakao and others (1994) and that young females may show a higher-than-male sensitivity to dopamine in the occurrence of the FO potential, as partly demonstrated in the present study (Figs. 2 and 3).

The reason why a stronger reaction to dopamine is revealed in young females could be because: i) the physiologic effects of dopamine which are mediated by specific receptors on target neurons are stronger in females; ii) the sensitivity to dopamine itself is higher in females; and iii) specific dopamine receptors in the retina are more numerous in females than in males.

Further investigation on more test subjects is needed to clarify the exact reason and mechanisms causing this difference based on sex in the young generation concerning sensitivity to dopamine, with special emphasis on the difference in sex in much younger or older people, in addition to *in vivo* and *in vitro* animal experiments.

Acknowledgments: We express our sincere thanks to Professor Yoshitsugu Inoue, Division of Ophthalmology and Visual Science, Department of Medicine of Sensory and Motor Organs, School of Medicine, Tottori University Faculty of Medicine, for his generous help.

References

1 Arden GB, Barrada A, Kelsey JH. New clinical test of retinal function based upon the standing potential of the eye. Br J Ophthalmol 1962;46:449–467.
2 Dawis S, Hoffmann H, Niemeyer G. The electroretinogram, standing potential and light peak of the perfused cat eye during acid-base changes. Vision Res 1985;25:1163–1177.
3 Dawis S, Niemeyer G. Dopamine influences the light peak in the perfused mammalian eye. Invest Ophthalmol Vis Sci 1986;27:330–335.
4 Dearry A, Burnside B. Dopamine induces light-adaptive retino-motor movements in teleost photoreceptors and retinal pigment epithelium. In: Bodis-Wollner I, ed. Dopaminergic mechanisms in vision. New York: Alan R. Riss; 1988. p. 109–135.
5 De Rouck A, Kayembe D. A clinical procedure for the simultaneous recording of fast and slow EOG oscillations. Int Ophthalmol 1981;3:179–189.
6 Dubocovich ML, Weiner N. Pharmacological differences between the D-2 autureceptor and D-1 dopamine receptor in rabbit retina. J Pharmacol Exp Ther 1985;233:747–754.
7 Gallemore RP, Griff ER, Steinberg RH. Evidence in support of photoreceptoral origin for the "light-peak substance". Invest Ophthalmol Vis Sci 1988;29: 566–571.
8 Gallemore RP, Steinberg RH. Effects of dopamine on chick retinal pigment epithelium. Invest Ophthalmol Vis Sci 1990;31:67–80.
9 Inoue M, Tamai A, Hatta S, Sasaki Y. Slow and fast oscillation electrooculography in central retinal vein occlusion: a comparison between affected eyes and fellow intact eyes. Yonago Acta Med 2003;46:65–75.
10 Jaffe MJ, Levinson PD, Zimmlichman R, Coen JC, Karson CN, De Monasterio FM. The Effect of metoclopramide on the Ganzfeld electroretinogram. Vision Res 1987;27:1693–1700.
11 Joseph DP, Miller SS. Apical and basal membrane ion transport mechanisms in bovine retinal pigment epithelium. J Physiol 1991;435:439–463.
12 Kawasaki K, Yanagida T, Yamamoto S, Yonemura D. Decrease of electro-oculographic potential under osmotic stress in man. Rinsho Ganka 1977;31:889–894 (in Japanese with English abstract).
13 Kebabian JW, Calne DB. Multiple receptors for dopamine. Nature 1979;277:93–96.
14 Kolder HE. Electro-oculography. Ophthalmologica 1974;169:127–140.
15 Kolder HE, Brecher GA. Fast oscillations of the

corneoretinal potential in man. Arch Ophthalmol 1966;75:232–237.
16 Maruiwa F, Kim S-D, Nao-i N, Sawada A. Effect of metocloparamide, dopamine receptor blocker, on the EOG light peak. Nippon Ganka Gakkai Zasshi 1992;96:375–380 (in Japanese with English abstract).
17 Nakao H, Miki N, Nagata M, Sasaki Y, Setogawa A, Narita A, et al. Recording of fast oscillations of the corneoretinal potential with an automated electro-oculograph Nidek EOG-2 in a series of normal subjects. Yonago Acta Med 1994;37:1–8.
18 Nguyen-Legros J, Simon A, Mousafi F. Dopaminergic terminals from interplexiform cells reach the outer nuclear layer in rat and monkey retinas. Invest Ophthalmol Vis Sci 1989;30 (Suppl):120.
19 Nikara T, Sato S, Mita T, Takamatsu T. An analysis of oscillatory potentials elicited by slow repetitive light stimulation in cat eye. Iwate Igaku Zasshi 1974;26:414–418 (in Japanese with English abstract).
20 Schulze-Delrieu K. Metoclopramide. Gastroenterology. 1979;77:768–779.
21 Shirao Y, Steinberg RH. Mechanisms of effects of small hyperosmotic gradients on the chick RPE. Invest Ophthalmol Vis Sci 1987;28:2015–2025.
22 Steinberg RH, Linsenmeier RA, Griff ER. Three light-evoked responses of the retinal pigment epithelium. Vision Res 1983;23:1315–1323.
23 Tamai A, Hamamoto J, Hasegawa J, Baba T, Hatta S, Sasaki Y. Fast and slow oscillation electrooculography in Harada disease. Yonago Acta Med 2004; 47:37–44.
24 Thaler ARG, Lessel MR, Heilig P, Scheiber V. The fast oscillation of the electro-oculogram. Influence of stimulus intensity and adaptation time on amplitude and peak latency. Ophthalmic Res 1982;14: 210–214.
25 Tran VT, Dickman M. Differential localization of dopamine D_1 and D_2 receptors in rat retina. Invest Ophthalmol Vis Sci 1992;33:1620–1626.
26 Weleber RG. Fast and slow oscillations of the electro-oculogram in Best's macular dystrophy and retinitis pigmentosa. Arch Ophthalmol 1989;107:530–537.

Received November 2, 2005; accepted November 17, 2005

Corresponding author: Akihiko Tamai, MD