Clinical Studies of Human Erect Posture

—To my Father—

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A human body in erect posture seems to be stationary in condition. However, it moves slightly all the time, not only in normal but in disturbed equilibrium. In human body the maintenance of equilibrium is complicated because of his erect posture, his erect gait and his need to do skillful actions. It is generally accepted by various researchers that equilibrium of human body is controlled by a number of impulses, such as 1) labyrinthine discharge from the maculae and cristae, 2) proprioceptive impulses from deep tissues, that is to say, muscles, tendons, joints, neck, trunk, and limbs, 3) exteroceptive impulses from skin and surface, and 4) visual impulses from the retina. The correlation of these above mentioned impulses seems to be managed in the higher centers of the central nervous system. The labyrinth is of importance to control in equilibrium of body and the cerebellum is the main organ to maintain the antigravity muscles activity. The muscular tonus, particularly of antigravity muscles, is responsible to maintain the erect posture.

The labyrinthine discharge in erect posture are described as a righting reflex or reaction. In normal righting reaction a subject in erect posture enable to maintain normal equilibrium, on the other hand in cases with distroyed righting reaction the patient in erect posture does not enable to maintain his equilibrium of body and falls towards the affected side.

Equilibrium of human body in erect posture is examined clinically by static function tests, such as 1) Romberg test, 2) Mann's test and 3) Goniometer test. There have been a number of reports as to results from static function tests carried out in human subjects, both normal and patients up-to-date. For example, in our Department Tsujikawa (1965)[1] studied the human equilibrium by static function tests in 20 normal adults by using acceleration registrography (Kitahara), Nishimura (1962)[2] performed on static function tests in 86 cases with complaining vertigo using the acceleration registrography, and Ishihara (1975)[3] and Honjo & Ishihara (1971)[4] carried out static function tests in 54 cases with complain-

ing vertigo by using the acceleration registrography and divided results obtained by registrograms into six groups.

The purpose of this paper is to analyze statistically the results from static function tests in cases with complaining of vertigo.

MATERIAL AND METHODS

The present analysis of its clinical features is based upon the study, made possible through the courtesy of my colleagues in Department of Otolaryngology, Yamaguchi University, School of Medicine, of 220 cases with vertigo. These we have examined in the course of the last three years. Age and sex distribution are tabulated in Table 1. It will be seen

Table. 1. Age and sex distribution of 220 cases

	(Total)	0–19	20–29	30–39	40–49	50–59	60–69	+70
Male	112	2	13	23	26	23	19	6
Female	108	5	14	25	23	22	18	1
Total	220	7	27	48	49	45	37	7

Table. 2. Clinical diagnosis of 220 patients

Disease	Number	%	Disease	Number	%
Meniere's disease	43	19.55	SM intoxication	4	1.8
Cerebral vascular lesions	42	19.1	Spinal ataxia	3	1.4
Head trauma	19	8.6	Cerebellar ataxia	3	〃
Vestibular neuronitis	15	6.8	Circumscribed labyrinthitis	3	〃
Cervisal vertigo	10	4.5	Harada's disease	3	〃
Hypertension	8	3.6	Post-meningitis	2	0.9
Dead labyrinth	7	3.2	Motion sickness	1	0.45
Sudden deafness	7	〃	Thinner tntoxication	1	〃
Benign paroxysmal positional vertigo	6	2.7	Philopon intoxication	1	〃
Brainstem lesion	6	〃	Organic phosphate poisoning	1	〃
Vegetative dystonia	6	〃	Tabes dorsalis	1	〃
Brain tumour	5	2.3	Wallenberg syndrome	1	〃
Hypotension	5	〃	Epilepsy	1	〃
Mercury poisoning	5	〃	Congenital nystagmus	1	〃
Hormonal disorders	5	〃	Strabismus	1	〃
Anemia	4	1.8			

that vertigo ic complained of the age group 30 to 50 without preference for sex. The diagnostic categories are given in Table 2.

METHODS

1. History.

In all patient, clinical history in detail was recorded by means of tapecorder.

2. Physical examination.

Each patient has received a complete otolaryngological survey. Pure tone audiometry by air and bone conduction has been done in each case, supplemented by Bekesy type's audiometry. As a kinetic function test, gait, stepping and writing have been performed. Spontaneous nystagmus has been examined in the condition, such as eyes opened in dark, using Frenzel's glasses and eye closed. Gaze nystagmus has been also checked. Positional nystagmus has been tested by means of Nylen's method. The fistula symptom has been searched for routinely in a suppurative ear.

A vestibular stimulation has included caloric testing by the Fitzgerald-Hallpike method and rotatory examination by Barany's technique, supplemented by galvanic stimulation. When an ear failed to respond to calorization of Fitzgerald-Hallpike method, it has been douched with ice water at 0 to 3° C. One ml of normal saline or antibiotic solution at 5° C has been employed in cases with a perforation of the eardrum. For recording the nystagmus an electronystagmography has been utilized.

The neurological examinaiton has consisted of tests for the action of cranial nerves two to ten inclusive, cerebellar function and posterior column integrity. The routine of clinical examination has included tests of visual acuity, blood pressure, peripheral blood, blood chemistry and serum electrolyte. As occasional demands, X-ray of the mastoids, angiography of the cerebral artery and others have been tested.

3. Static function tests.

In order to examine the righting reaction in patients of the present study, Romberg's test, Mann's test and Goniometer test have been performed.

a) Romberg's test.

Although Romberg's test is rather classical, this procedure is performed from choice by otologists up-to-date because of a simple and excellent test in the light of present. For this test the patients have been required to stand on the flat floor with both feet close together to eliminate the

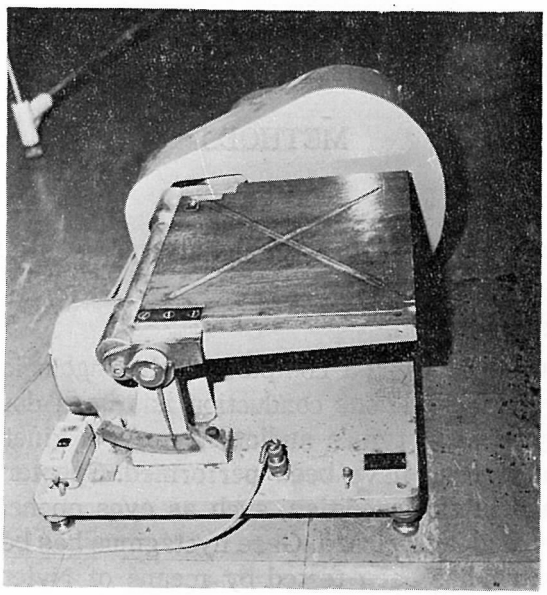


Fig. 1. An electrical goniometer (Honjo).

At angular acceleration of 1.4°/sec² and a constant angular velosity of 1°/sec.

proprioceptive factor as far as possible and with their eyes open or closed.

b) Mann's test.

The patients have been required to stand with one foot in front of the other in Mann's test, so that the heel of the anterior foot has touched the toe of the posterior foot. Mann's position is rather unstable than Romberg's position, so that in my experiences the patients, particularly old woman, have shown some difficulty to maintain erect posture.

c) Goniometer test.

For Goniometer test an electrical goniometer has been used, which was devised by Honjo (Fig. 1.). This instrument inclines from horizontal plane to 30° at angular acceleration of 1.4°/sec² and a constant angular velosity of 1.0°/sec. From the erect posture on the horizontal plank of the goniometer the patients have been inclined forwards, backwards and both sides. During the inclination the patients have kept their eyes opened or closed.

4. Recording the righting responses.

For recording the righting responses of the patients obtained by static function tests the author has utilized an acceleration registrography

described first by Kitahara (1965)[5]. For this purpose two bonded resistance wire strain-gage type accelerometers (Kyowa Dengyo AS-IC. Capacity lg) of which directions of action are lateral or anteroposterior planes have used. As shown in Fig. 2 these accelerometers placed on the top of the patient's head enable to changed mechanical quantity of body movements into electrical quantity of resistance (potential). The accelerometer consists of two pairs of resistance wires which are pasted up on a spring plate sustaining a weight. These two pairs of resistance wires are conne-

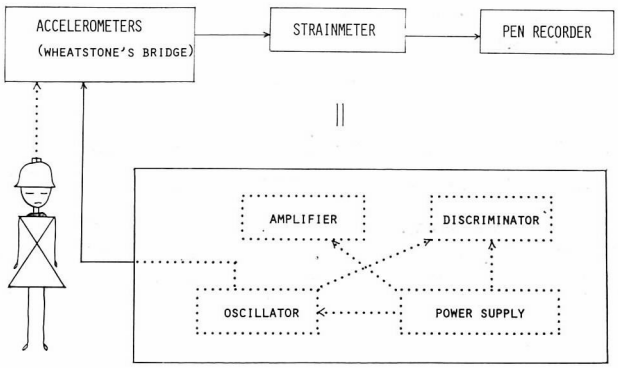


Fig. 2. Block diagram of instruments and posture of subject.

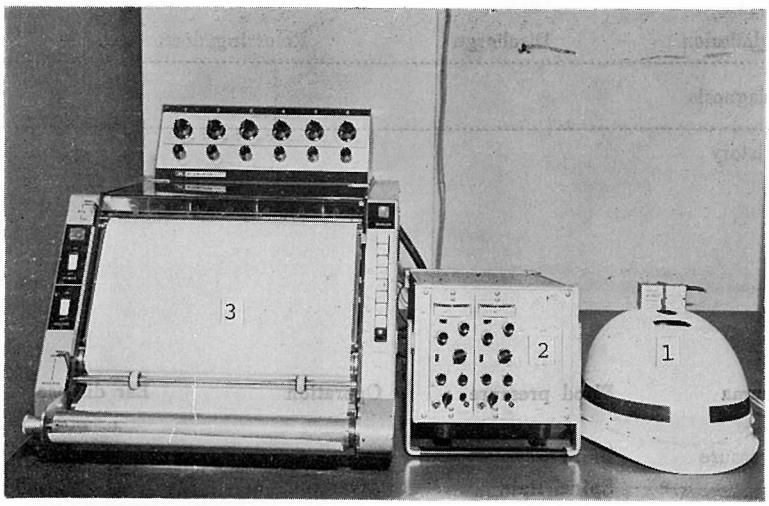


Fig. 3. The instruments used in the present study.

1. Two accelerome tersfixed on the helmet.
2. Strain meters.
3. Pen rcorder.

cted in Wheatstone's bridge. The bridge is activated by an oscillator in the strain meter, so that the sine wave of the oscillator frequency is modulated by the signal wave. In the strain meter the output of the accelerometer is applied to an amplifier and then to silicone diode discriminater. The output from the strain meters has been recorded with pen recorder (San-ei Sokki, 8S12). In Fig. 3 is shown the instruments used.

5. Collection of data.

Those facts which in patients have been considered relevant have been recorded on a card in order to arrange and analyze the data obtained in the present study (Fig. 4 and 5).

RESULTS

Honjo and Ishihara (1971)[4] carried out static function tests, such as Romberg's test, Mann's test and Goniometer test in patients with vertigo and classified results (acceleration registrograms) obtained by the tests into the following six types: Type I. The waves of acceleration registrograms are within normal limits with eyes open or closed; Type II. The

Inner ear	Head trauma	Psychiat.	Neurol.	Eye d.	Cardio. vascular	Hormone	

Name aged, OC No. A. 19

Admission Discharge Referring doctor O.

Diagnosis

History

Head trauma	Blood pressure	Operation	Ear disease
Blood Pressure	Brain wave	Lues	Blood
E. C. G.	Spinal fluid	Liver function	
Hypertension	Psycho-neurol.	Hormonal	
Anemia	Ophthalmol.		
Arteriosclerosis	Gynecologic		

Fig. 4.

	Mo. day 19.	Mo. day 19.	Mo. day 19.
	Normal abnormal	Normal abnormal	Normal abnormal
1. Romberg test			
2. Mann's test			
3. Goniometer test			
4. Stepping test			
5. Walking test			
6. Writing test			
7. Nystagmus			
a. spontaneous			
b. closed eyes			
c. covered eyes			
d. gaze & positional			
f. positioning			
8. Fistula test			
	c.	c.	c.
	a.	a.	a.
9. Caloric test			
	CP	CP	CP
	DP	DP	DP
10. Rotation test			
11. OKP test			
12. ET test			
13. Hearing test			
conductive,	c.	c.	c.
perceptive,	p.	p.	p.
mixed	m.	m.	m.
14. X-ray of the ears			
15.			
16.			

Fig. 5.

waves of acceleration registrograms obtained by Mann's test and Goniometer test with eyes closed show larger than those of normal in frequency otherwise normal; Type III. The waves of acceleration registrograms obtained by Mann's test and Goniometer test with eyes open and closed show larger than normal in frequency, notwithstanding normal by Romberg's test; Type IV. The waves of acceleration registrograms obtained by three tests show larger than those of normal in frequency; Type V. The waves shows abnormal peculier spike in all tests; Type VI. The waves obtained by only Goniometer test show larger than normal in frequency with eyes open and closed. In Table 3. is shown a classification of acceleration registrograms (Honjo and Ishihara).

Table. 3. Classification of acceleration registrogram by Honjo and Ishihara.

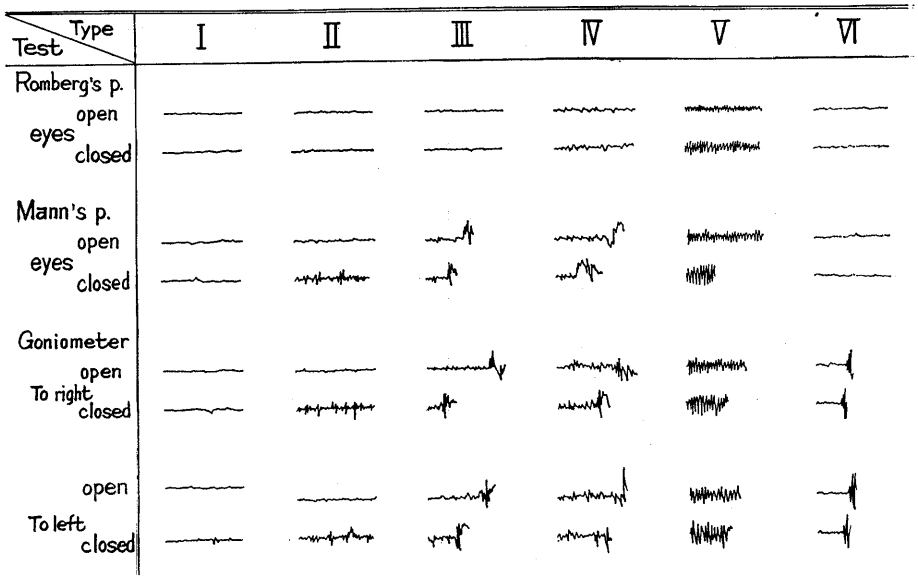


Table. 4. Pattern of acceleration registrogram in 220 cases with vertigo

Type	Number	%
I	69	31.4
II	80	36.4
III	19	8.6
IV	37	16.8
V	5	2.3
VI	10	4.5
Total	220	100.0

Acceleration registrograms of all 220 patients in this study have been classified into the patterns shown in Table 4 according to classification of Honjo and Ishihara above mentioned.

As shown in Table 4 acceleration registrograms (ARG) of 69 patients (31.4%) consist with Type I which presents a normal righting response. It should be kept in mind that in spite of complaining vertigo ARG of those 69 patients show the normal pattern, that is Type I. ARG of 80 (36.4%), that is the greatest amount of 220 patients, consist with Type II and ARG of 5 (2.3%) that is the smallest amount, consist with Type V which presents abnormal peculiar spike.

1. Type I of ARG.

Diagnostic categories of 69 patients whose ARG presents Type I are as follows: Meniere's disease, 22; cerebral vascular lesion, 9; vestibular neuritis, 6; head trauma, 6; vegetative dystonia, 6; benign paroxysmal positional vertigo, 3; hypertension, 2; hypotension, 2; streptomycin poisoning, 2; and each one patient of Harada's disease, Hormonal disorder, cervical vertigo, brainstem lesion, Thinner poisoning, Wallenberg syndrome, and epilepsy.

The sixty nine patients with ARG Type I, that is normal righting reaction, have been examined for vestibular and optokinetic nystagmus. The results obtained are shown in Table 5. Spontaneous nystagmus presents in one patient with dead labyrinth. Positional nystagmus presents in 22 patients (31.9%) which consist of 6 Meniere's disease, 4 cerebral vascular lesions and each one of hypertension, hypotension, brainstem lesion, head trauma, Harada's disease, thinner intoxication, sudden deafness, streptomycin poisoning, benign paroxysmal positional vertigo, vestibular neuritis, hormonal disorders, and vegetative dystonia. Abnormal caloric response are elicited in 16 patients (23.2%) of which 12 patients show canal paresis and 4 patients present directional preponderance. Twelve patients presenting canal paresis consist of 7 Meniere's disease and each one of vestibular neuritis, streptomycin poisoning, head trauma, benign paroxysmal positional vertigo and hypertension, and four patients presenting directional preponderance consist of 3 Meniere's disease and 1 Harada's disease. Abnormal rotatory responses are elicited in 5 patients (7.5%) which consists of 2 Meniere's disease, and each one of cerebral vascular lesion, sudden deafness and head trauma. Abnormal patterns in optokinetic pattern test are seen in 9 patients (13.0%) which consist of 3 Meniere's disease, 3 cerebral vascular lesions and each one of brainstem lesion, epilepsia and sudden deafness. Abnormal pattern in eye-tracking test are seen in 14 patients (20.8%) which consist of 5 Meniere's desease, 3 cerebral vascular lesion and each one of hypertension, sudden deafness, epilepsia, Wallenberg syndrome, streptomycin poisoning and benign paroxysmal positional vertigo.

Table. 5. Abnormal responses of vestibular and optokinetic function in 69 patients with ARG of type I

Spontaneous nystagmus	Positional nystagmus	Caloric nystagmus	Rotatory nystagmus	Optokinetic pattern	Eye-tracking test
1	22	16	5	9	14
0.15%	31.9%	23.2%	7.2%	13.0%	20.3%

2. Type II of ARG.

Diagnostic categories of 80 patients whose ARG presents Type II are as follows: Meniere's disease, 18; cerebral vascular lesions, 17; cervical vertigo, 7; vestibular neuritis, 6; head trauma, 5; hypertension, 3; anemia, 3; benign paroxysmal positional vertigo, 3; sudden deafness, 2; hormonal disorder, 2; hypotension, 2; brain tumor, 2; post-meningitis, 2; and each one of dead labyrinth, streptomycin poisoning, circumscribed labyrinthitis, Harada's disease, Motion sickness, Mercury poisoning, organic phosphate poisoning and strabismus.

The eighty patients with ARG Type II have been examined for vestibular and optokinetic nystagmus. The results obtained are shown in Table 4. Spontaneous nystagmus presents in 3 patients (3.7%) which consist of each one of Meniere's disease, head trauma and strabismus. Positional nystagmus presents in 41 patients (51.2%) which consist of 12 Meniere's disease, 8 cerebral vascular lesions, 4 cervical vertigo, 4 head trauma, each one of hypertension, hypotension, Harada's disease, vestibular neuritis, post-meningitis, mercury poisoning and strabismus. Abnormal caloric response are elicited in 25 patients (31.2%) of which 21 patients show canal paresis and 4 patients present directional preponderance. Twenty one patients presenting canal paresis consist of 6 Meniere's disease, each two of cerebral vascular lesions, sudden deafness, head trauma, brain tumor, each one of hypertension, cervical vertigo, Harada's disease, hypotension, streptomycin poisoning, vestibular neuritis, and dead labyrinth, and four patients presenting directional preponderance consist of 2 cerebral vascular lesions and each one of cervical vertigo and vestibular neuritis. Abnormal rotatory responses are elicited in 11 patients (18.7%) which consist of 2 Meniere's disease, each two of cerebral vascular lesions and brain tumor and each one of hypertension, Harada's disease and dead labyrinth. Abnormal patterns in optokinetic pattern test are seen in 20 patients (25.0%) which consist of 5 cerebral vascular lesions, 4 Meniere's disease, 3 cervical vertigo, 2 head trauma and each one of post-meningitis, organic phosphate intoxication, brain tumor, anemia,

Table. 6. Abnormal responses of vestibular and optokinetic function in 80 patients with ARG of type Ⅱ

Spontaneous nystagmus	Positional nystagmus	Caloric nystagmus	Rotatory nystagmus	Optokinetic pattern	Eye-tracking Test
3	41	25	11	20	22
3.7%	51.2%	31.2%	13.7%	25.0%	27.5%

hormonal disorder and strabismus. Abnormal pattern in eye-tracking test are seen in 22 patients (27.5%) which consist of each five of cerebral vascular lesions and Meniere's disease, 3 of head trauma, 2 of cervical vertigo, and each one of organic phosphate intoxication, brain tumor, anemia, hormonal disorder, post-meningitis, strabismus and hypotension.

3. Type III of ARG.

Diagnostic categories of 19 patients whose ARG presents Type III are as follows: cerebral vascular lesions 5; dead labyrinth 2; and each one of Meniere's disease, vestibular neuritis, circumscribed labyrinthitis, Harada's disease, hormonal disorders, head trauma, brainstem lesions, hypotension, mercury poisoning, brain tumor, philopon intoxication and anemia.

The nineteen patients with ARG Type III have been examined for vestibular and optokinetic nystagmus. The results obtained are shown in Table 7. Spontaneous nystagmus presents in one patient (5.3%) with dead labyrinth. Positional nystagmus presents in 7 patients (36.8%) which consist of each one of vestibular neuritis. organic phosphate intoxication, cerebral vascular lesions, brain stem lesions, hypotension and dead labyrinth. Abnormal caloric responses are elicited in 5 patients (26.3%) of which 4 patients show canal paresis and one shows directional preponderance. Four patients presenting canal paresis consist of 2 dead labyrinth and each one of Harada's disease and vestibular neuritis. One patient with mercury poisoning shows directional preponderance. Abnormal rotatory responses are elicited in 4 patients (21.1%) which consist of 2 dead labyrinth and each one of cerebral vascular lesions and hormonal disorders. Abnormal optokinetic patterns are seen in 10 patients (52.6%) which consist of 3 cerebral vascular lesions, and each one of philopon intoxication, hypotension, Meniere's disease, anemia, mercury poisoning, dead labyrinth and hormonal disorders. Abnormal patterns in eye-tracking test are seen in 12 patients (63.2%) which consist of 4 cerebral vascular lesions, and each one of brainstem lesions, vestibular neuritis, Harada's disease, Meniere's disease, mercury intoxication, philopon intoxication, hormonal disorders and anemia.

Table. 7. Abnormal responses of vestibular and optokinetic function in 19 patients with ARG of type III

Spontaneous nystagmus	Positional nystagmus	Caloric nystagmus	Rotatory nystagmus	Optokinetic pattern	Eye-tracking test
1	7	5	4	10	12
5.3%	36.8%	26.3%	21.1%	52.6%	63.2%

4. Type IV of ARG.

Diagnostic categories of 37 patients whose ARG presents Type IV are as follows: cerebral vascular lesions 7; head trauma 6; brainstem lesions 3; spinal ataxia 3; dead labyrinth 4; each two of cervical vertigo, hypertension, cerebellar ataxia, vestibular neuritis;, and mercury poisoning and each one of brain tumor, Meniere's disease, streptomycin poisoning, and sudden deafness. The thirty seven patients with ARG Type IV have been examined for vestibular and optokinetic nystagmus. The results obtained are shown Table 8. Spontaneous nystagmus presents in one patient (2.7%) with brain tumor. Positional nystagmus presents in 15 patients (40.5%) which consist of each three of cerebral vascular lesions, head trauma and brainstem lesions, and each one of cerebellar ataxia, cervical vertigo, dead labyrinth, brain tumor, vestibular neuritis and Meniere's disease. Abnormal caloric responses are elicited in 10 patients (27.0%) of which 9 patients show canal paresis and one patient with cervical vertigo show directional preponderance. Nine patients presenting canal paresis consist of 4 dead labyrinth, 2 cerebral vascular lesions, and each one of Meniere's disease, vestibular neuritis and head trauma. Abnormal rotatory responses are elicited in 7 patients (18.9%) which consist of 3 dead labyrinth and 2 head trauma, and each one of Meniere's disease and cervical vertigo. Abnormal patterns of optokinetic responses are seen in 25 patients (67.6%) which consist of each 5 of cerebral vascular lesions and head trauma, each two of hypertension and cerebellar ataxia, spinal ataxia, cervical vertigo and vestibular neuritis, and each one of brainstem lesions, mercury intoxication, Meniere's disease, dead labyrinth and brain tumor. Abnormal responses in eye-tracking test are seen in 20 patients (54.1%) which consist of each three of cerebral vascular lesions, head trauma and each two of cerebellar ataxia, mercury intoxication and brainstem lesions, and each one of cervical vertigo, spinal ataxia, Hypertension, brain tumor, Meniere's disease, vestibular neuritis, dead labyrinth and sudden deafness.

Table. 8. Abnormal responses of vestibular and optokinetic function in 37 patients with ARG of type Ⅳ

Spontaneous nystagmus	Positional nystagmus	Caloric nystagmus	Rotatory nystagmus	Optokinetic pattern	Eye-tracking test
1	15	10	7	25	20
2.7%	40.5%	27.0%	18.9%	67.6%	54.1%

5. Type V of ARG.

Diagnostic categories of 5 patients whose ARG presents Type V are as follows: each one of cerebral vascular lesion; brainstem lesion; mercury poisoning; cerebellar ataxia; and tabes dorsalis. The five patients with ARG Type V have been examined for vestibular and optokinetic nystagmus. The results obtained are shown in Table IX. Spontaneous nystagmus presents in no patient. Positional nystagmus presents in 3 patients (60%) which consist of each one of tabes dorsalis, brainstem lesion and cerebellar ataxia. Abnormal response in caloric or rotatory nystagmus presents in no patient. Abnormal patterns in optokinetic nystagmus are seen in 2 patients (40%) with cerebral vascular lesion and cerebellar ataxia. Abnormal patterns in eye-tracking test are seen 2 patients (40%) with tabes dorsalis and cerebellar ataxia.

Table. 9. Abnormal responses of vestibular and optokinetic function in 5 patients with ARG of type V

Spontaneous nystagmus	Positional nystagmus	Caloric nystagmus	Rotatory nystagmus	Optokinetic pattern	Eye-tracking test
0	3	0	0	2	2
0%	60%	0%	0%	40%	40%

6. Type VI of ARG.

Diagnostic categories of 10 patients whose ARG presents Type VI are as follows: cerebral vascular lesions 3; and each one of head trauma, hypertension, brain tumor, Meniere's disease, circumscribed labyrinthitis, hormonal disorder and congenital nystagmus. The ten patients with ARG Type VI have been examined for vestibular and optokinetic responses. The results obtained are shown in Table 10. Spontaneous nystagmus presents in 2 patients (20%) with Meniere's disease and congenital nystagmus. Positional nystagmus presents in 4 patients (40%) which consist of each one of Meniere's disease, hypertension, circumscribed labyrinthitis and congenital nystagmus. Abnormal caloric responses are elicited in 2 patients with hormonal disorder showing canal paresis and Meniere's disease showing directional preponderance. Abnormal rotatory responses are elicited in one patient (10%) with circumscribed labyrinthitis. Abnormal patterns of optokinetic responses are seen in 4 patients (40%) which consist of each one of hypertension, congenital nystagmus, cerebral vascular lesion and brain tumor. Abnormal patterns in eye-tracking test are seen in 4 patients (40%) which consist of each one of congenital

Table. 10. Abnormal responses of vestibular and optokinetic function in 10 patients with ARG of type Ⅵ

Spontaneous nystagmus	Positional nystagmus	Caloric nystagmus	Rotatory nystagmus	Optokinetic pattern	Eye-tracking test
2	4	2	1	4	4
20%	40%	20%	10%	40%	40%

nystagmus, cerebral vascular lesion, brain tumor and hormonal disorder.

7. Comparison between each Type of ARG as to abnormal responses of vestibular and optokinetic functions.

1). Comparison between Type I and Type II (Table V and VI). As above mentioned, Type I of ARG correspond with ARG in normal righting reactions of human subjects. Compared with abnormal responses of vestibular and optokinetic functions in patients consisted of Type I of ARG, in patients showing Type II of ARG the incidences of abnormal responses increase in spontaneous nystagmus, positional nystagmus, caloric or rotatory nystagmus, and optokinetic nystagmus.

2). Comparison between Type II and Type III (Table VI and VII).

Comparing with abnormal responses of vestibular and optokinetic reactions in patients showing Type II of ARG, in patients showing Type III of ARG an incidence of positional nystagmus decreases while the incidences of abnormal patterns in optokinetic tests increase in optokinetic pattern test or eye-tracking test.

3). Comparison between Type IV and Type V or Type VI (Table 8, 9 and 10).

Comparing with abnormal responses of optokinetic reaction in patients showing Type IV of ARG, the incidences of abnormal patterns in optokinetic pattern test and eye-tracking test of Type V and VI of ARG decrease. As to an incidence of abnormal responses of spontaneous, positional, and caloric reactions, there is no obvious difference between Type IV and Type V or VI.

4). Comment.

From results above mentioned, it seems to be important to note that the more the righting reactions are disturbed, the more abnormal responses in nystagmus reaction increase.

8. The diagnostic categories,and ARG distribution in each disease.

In Table XI, XII and XIII are shown the diagnostic categories and Type distribution in 220 patients. As shown in these Tables, acceleration

Table 11. Diagnostic categories and distribution of types in ARG. (1)

	Total	I	II	III	IV	V	VI
Meniere's disease	43	22(51.2%)	18(41.9%)	1(2.3%)	1(2.3%)		1(2.3%)
Circumscribed labyrinthitis	3		1	1			1
Harada's disease	3	1	1	1			
Sudden deafness	7	4	2		1		
Motion sickness	1		1				
Dead labyrinth	7		1	2	4		
SM intoxication	4	2	1		1		
Benign paroxysmal positional vertigo	6	3	3				
Vestibular neuronitis	15	6(40%)	6(40%)	1(6.7%)	2(13.3%)		
Head trauma	19	6(31.6%)	5(26.3%)	1(5.25%)	6(31.6%)		1(5.25%)

Table. 12. Diagnostic categories and distribution of types in ARG. (2)

	Total	I	II	III	IV	V	VI
Brain tumour	5		2	1	1		1
Brainstem lesions	6	1		1	3	1	
Cerebellar ataxia	3				2	1	
Cerebral vascular lesions	42	9(21.4%)	17(40.5%)	5(11.9%)	7(16.7%)	1(2.4%)	3(7.1%)
Post-meningitis	2		2				
Wallenberg syndrome	1	1					
Epilepsy	1	1					
Mercury poisoning	5		1	1	2	1	
Thinner intoxication	1	1					
Philopon intoxication	1			1			

Table. 13. Diagnostic categories and distribution of types in ARG. (3)

	Total	I	II	III	IV	V	VI
Organic phosphate poisoning	1		1				
Spinal ataxia	3				3		
Tabes dorsalis	1					1	
Cervical vertigo	10	1(10%)	7(70%)		2(20%)		
Hypertension	8	2	3		2		
Hypotension	5	2	2	1			1
Anemia	4		3	1			
Vegetative dystonia	6	6					
Hormonal disorders	5	1	2	1			1
Congenital nystagmus	1						1
Strabismus	1		1				

registrograms (ARG) in patients with an identical diagnostic category do not belong the same Type of ARG, but divide into a few Types. For example, ARG of 43 patients with Meniere's disease are divided into the following Types: 22 (51.9%) in Type I; 18 (41.9%) in Type II; 1 (2.3%) in Type III; 1 (2.3%) in Type IV; and 1 (2.3%) in Type VI. ARG of 42 patients with cerebral vascular lesions are divided into the following Types: 9 (21.4%) in Type I; 17 (40.5%) in Type II; 5 (11.9%) in Type III, 7 (16.7%) in Type IV; 1 (2.4%) in Type V; and 3 (7.1%) in Type VI.

9. Abnormal responses of vestibular and optokinetic reactions in patients with Meniere's disease (Table 14).

Table. 14. Abnormal responses of vestibular and optokinetic function in 43 cases with Meniere's disease

ARG		Caloric		Spont. Nyst.	Positional nyst.				OKP	ETT
					Direction fixed			Direction Changed		
Type	(Numbers)	CP	DP		Affected.	Opposite.	Unknown.			
I	22	5	3	0	3	3	1	0	2	2
II	18	6	1	1	6	4	0	4	3	3
III	1	0	0	0	0	0	0	0	1	1
IV	1	1	0	1	0	0	1	0	1	1
V	0	0	0	0	0	0	0	0	0	0
VI	1	0	1	1	0	1	0	0	0	0
Total	43	12	5	3	9	8	2	4	7	7
%	100	27.9	11.6	7.0	20.9	18.6	4.7	9.3	16.3	16.3

Table. 15. Abnormal responses of vestibular and optokinetic function in 15 cases with vestibular neuronitis

ARG		Caloric		Spont. Nyst.	Positional Nyst.		OKP	ETT
Type	(Numbers)	CP	DP		diretion fixed	Direction changed		
I	6	0	1	0	0	1	0	0
II	6	3	2	0	2	0	0	0
III	1	1	0	0	1	0	0	1
IV	2	1	0	0	1	0	2	1
V	0	0	0	0	0	0	0	0
VI	0	0	0	0	0	0	0	0
Total	15	5	3	0	4	1	2	2
%	100	33.3	20	0	26.7	6.7	13.3	13.3

As shown in Table 14, compared with positional nystagmus in patients of ARG Type I, an incidence of this nystagmus in patients of ARG Type II increases, notwithstanding no outstanding difference in other response.

10. Abnormal response of vestibular and optokinetic reactions in patients with vestibular neuritis (Table 15).

As shown in Table 15, compared with caloric responses in patients of ARG Type I, an incidence of these responses in patients of ARG Type II increases, notwithstanding no definite difference in other responses.

11. Abnormal responses of vestibular and optokinetic reactions in patients with head trauma (Table XVI).

As shown in Table 16, compared with positional nystagmus in patients of ARG Type I, an incidence of this nystagmus in patients of ARG Type II and Type IV. As to the optokinetic reactions, the incidence in patients of ARG Type II and IV increase comparing with patients of other Types.

12. Abnormal responses of vestibular and optokinetic reactions in patients with cerebral vascular lesions (Table XVII).

As shown in Table 17, it seems to be important to note that in patients with cerebral vascular lesions no spontaneous nystagmus and no abnormal response in caloric reaction present except in ARG Type II, an incidence of abnormal responses in optokinetic reactions increases in ARG Type II, III and IV.

13. Abnormal responses of vestibular and optokinetic reactions in patients with cardiovascular lesions (Table 18).

Table. 16. Abnormal responses of vestibular and optokinetic function in 19 cases with head trauma

ARG		Caloric		Spont. Nyst.	Positional Nyst.		OKP	ETT
Type	(Numbers)	CP	DP		direction fixed	Direction changed		
I	6	1	0	0	0	1	0	0
II	5	4	0	0	3	1	2	3
III	1	0	0	0	0	0	0	0
IV	6	1	0	0	3	1	5	3
V	0							
VI	1	0	0	0	0	0	0	0
Total	19	6	0	0	6	3	7	6
%	100	31.6	0	0	31.6	15.8	36.8	31.6

Table. 17. Abnormal responses of vestibular and optokinetic in 42 with cerebral vascular lesions

ARG		Caloric	Spon . Nyst.	Positional Nyst.		OKP	ETT
Type	(Numbers)			Direction fixed	Direction changed		
I	9	0	0	1	1	2	2
II	17	3	0	6	3	5	6
III	5	0	0	0	1	3	4
IV	7	0	0	1	2	6	3
V	1	0	0	0	0	1	0
VI	3	0	0	0	0	1	1
Total	42	3	0	8	7	18	16
%	100	7.1	0	19.0	16.7	42.9	38.1

Table. 17. Abnormal responses of vestibular and optokinetic function in 17 cases with cardio-vascular lesion

ARG		Caloric		Spont. Nyst.	Positional Nyst.		OKP	ETT
Type	(Numbers)	CP	DP		Direction fixed	Direction changed		
I	4	0	0	0	2	0	0	1
II	8	1	1	0	1	1	1	2
III	2	0	0	0	0	1	2	1
IV	2	0	0	0	0	0	2	1
V	0	0	0	0	0	0	0	0
VI	1	0	0	0	1	0	1	0
Total	17	1	1	0	4	2	6	5
%	100	5.9	5.9	0	23.5	11.8	35.3	29.4

As shown in Table 18, it is considered to keep in mind that in patients with cardiovascular lesions there is no abnormal vastibular response with a few exception.

14. Reports of cases.

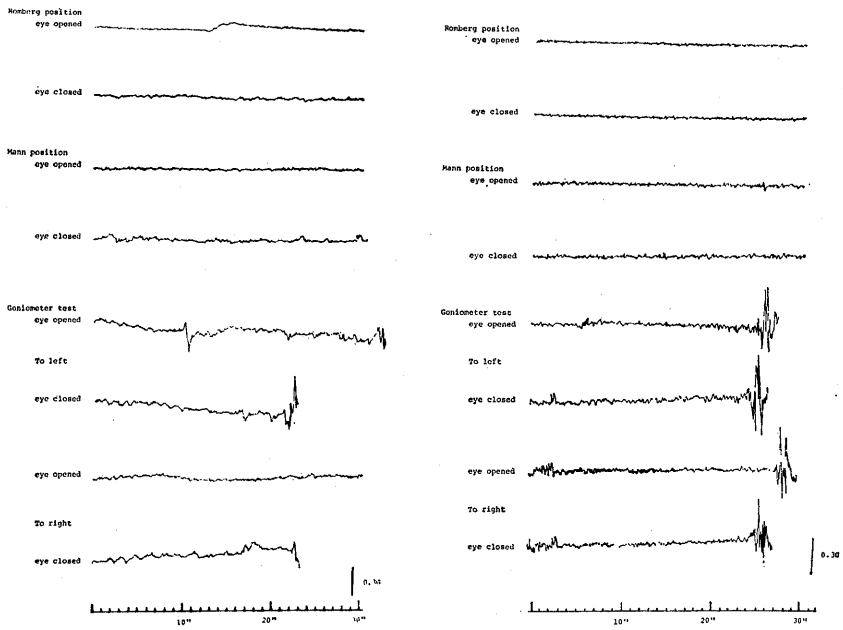
As the example in each type of the acceleration registrogram recorded in this study, the following cases are presented in order to make more clear the difference of each type.

1) Cases in Type I.

a) A 55-year-old woman with right sided Meniere's disease. She had hearing loss and tinnitus on the right side for 20 years. She had an attack of vertigo with nausea one year prior to the examination. Since then she

had the similar attacks of 8 times. Results obtained by static function test showed Type I of ARG (Fig. 6, a). The writing and stepping functions showed normal. There was no spontanous or positional nystagmus. Caloric response showed directional preponderance to the left side, and result of rotation test showed abnormal response. Results of eye tracking test and optokinetic pattern test showed normal.

b) A 39-year-old man with head injury. He had head injury four years before the examination. Since one month before the examination, he had faint sensation without tinnitus and hearing loss. Results obtained by static function tests showed Type I of ARG (Fig. 6, b). The stepping, walking and writing functions showed normal. There was no spontanous or positional nystagmus. Results of caloric and rotation tests showed normal responses. Results of eye tracking test and optokinetic pattern tests showed normal.



a. A 55-year-old woman with right sided Meniere's disease.
b. A 39-year-old with head trauma.

Fig. 6. (a, b). The example in Type I of acceleration registrogram.

2) Cases in Type II.

a) A 41-year-old woman with right sided Meniere's disease. She had hearing loss (40db) with tinnitus on the right side for several years. She

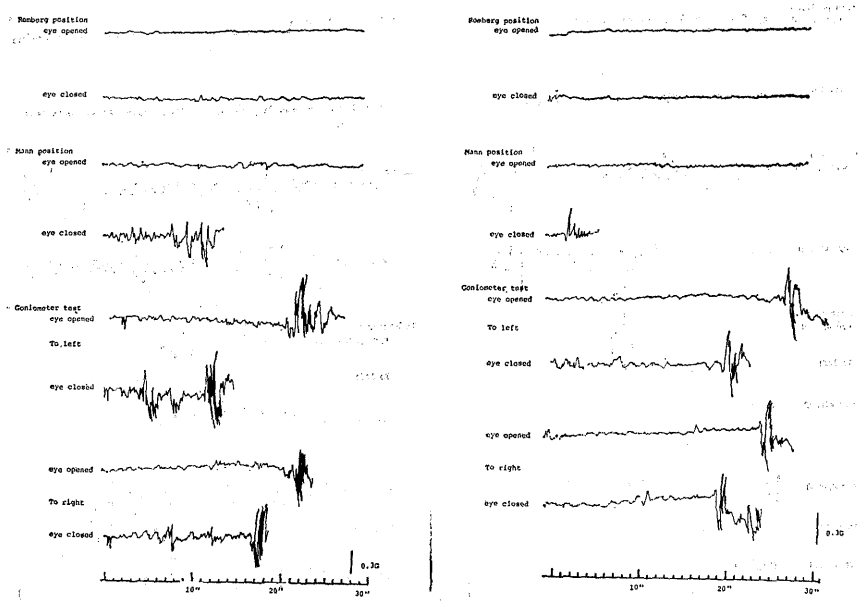
had an attack of vertigo for a day with exacerbated tinnitus on the right side three months prior to the examination. Since then she had the similar attacks three times. The last attack occurred six days before the examination. Results obtained by static function test showed Type II of ARG (Fig. 7, a). She had a tendency to fall to the left side in Mann's test. There was no spontanous nystagmus. There was positional nystagmus beating to the right side in all head positions. Result of caloric test showed canal paresis on the right side, and result of rotation test showed normal responses on both sides. Result of ETT presented slightly saccadic, and OKP showed normal.

b) A 34-year-old man with right sided vestibular neuritis. He had an attack of vertigo with vomiting following a common cold three months prior to the examination. Since then he had vertigo for thirty seconds whenever he changed quickly his head position. He never had tinnitus or hearing loss. Results obtained by static function test showed Type II of ARG (Fig. 7, b). The stepping and writing functions showed normal. There was no spontanous or positional nystagmus. Result of caloric test showed canal paresis on the right side, and result of rotation test showed normal response. OKP and result of ETT showed normal.

c) A 55-year-old woman with cerebral vascular lesion. She complained of faint sensation when she changed her posture quickly for 10 years. Two weeks before the examination she had rotatory vertigo for only one minute. She complained of severe headache following the vertigo, and she had the same attacks when she changed head position. Results obtained by static function test showed Type II of ARG (Fig. 7, c). The stepping and writing functions showed normal. There was no spontanous or positional nystagmus. Results of caloric and rotation tests showed normal responses. Results of ETT presented slightly saccadic pattern, and OKP showed normal.

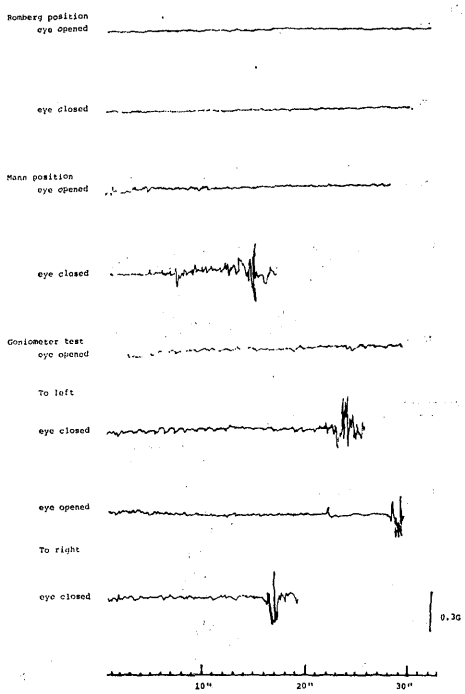
3) Cases in Type III.

a) A 52-year-old woman with right sided vestibular neuritis. Three weeks before the examination, she had vertigo when she changed her posture quickly. She had sometimes vomiting, and vertigo was not rotatory in nature but nearly faint. She had mastitis and was treated with drugs for 10 days before the attack. She had no tinnitus or hearing loss. Results obtained by static function test showed Type III of ARG (Fig. 8, a). The stepping and writing functions showed normal. There was positional nystagmus beating to the left side in all head positions. Result of caloric test showed canal paresis on the right side. Results of rotation test and OKP were within normal limits. Result of ETT showed abnormal pattern.



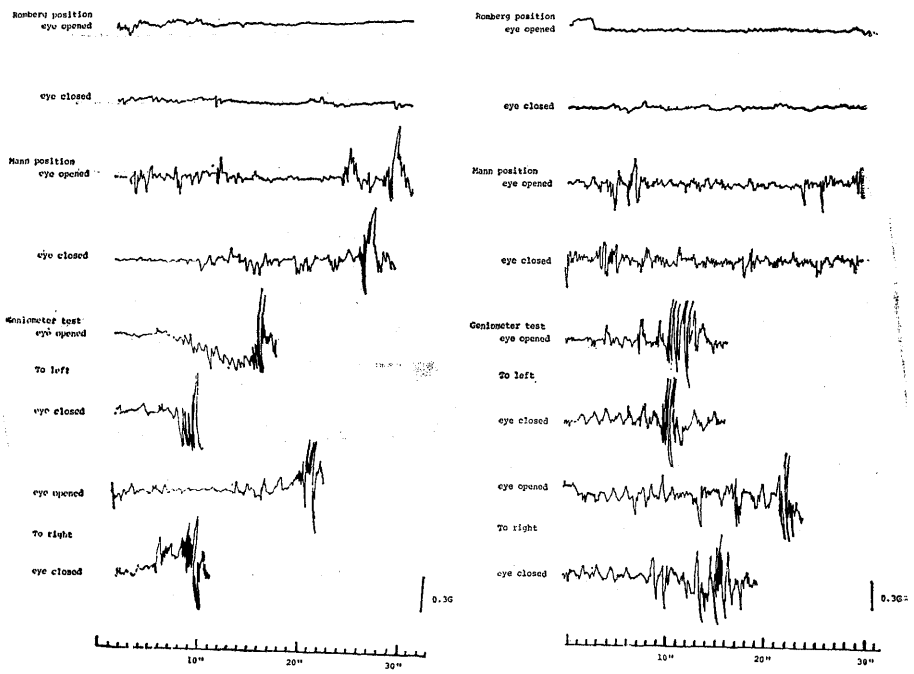
a. A 41-year-old woman with right sided Meniere's disease.
b. A 34-year-old man with right sided vestibular neuritis.

Fig. 7 (a, b). The example in Type Ⅱ of acceleration registrogram.



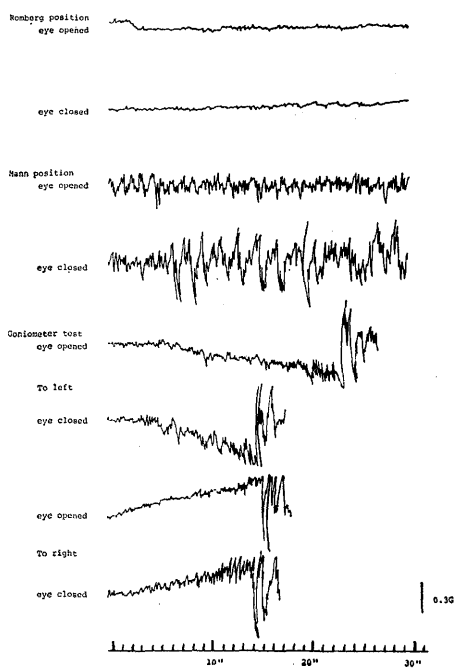
c. A 55-year-old woman with cerebral vascular lesion.

Fig. 7(c). The example in Type Ⅱ of acceleration registrogram.



a. A 52-year-old woman with right sided vestibular neuritis.
b. A 62-year-old man with Harada's disease.

Fig. 8. (a, b). The example in Type Ⅲ of acceleration registrogram.

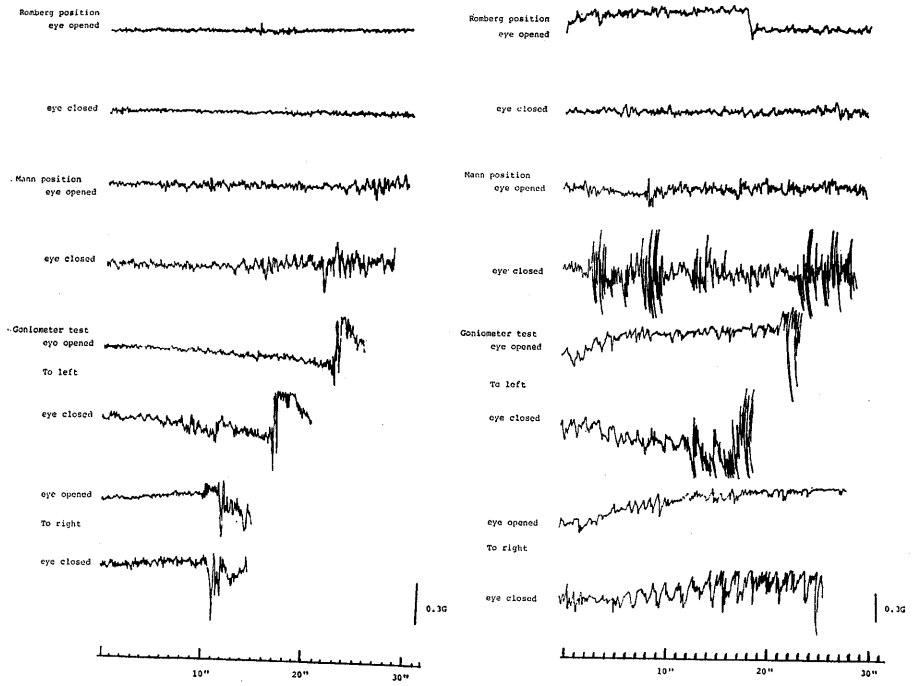


c. A 39-year-old man with head injury.

Fig. 8(c). The example in Type Ⅲ of accelerarion registrogram.

b) A 62-year-old man with Harada's disease. He had the blurring of vision on the right side 6 weeks before the examination. Three days after the onset of the right visual disturbance, the left sided vision was disturbed. At the same time he complained of unsteadiness of gait, hearing loss with tinnitus and ear plugged sensation. Unsteadiness was subsided following with recovery of vision. Results obtained by static function test showed Type III of ARG (Fig. 8, b). The stepping and writing functions showed normal. There was no spontanous or positional nystagmus. Result of caloric test showed canal paresis on the right side. Result of rotation test showed normal. OKP showed normal, but result of ETT showed abnormal pattern.

c) A 39-year-old man with head injury. Four years before the examination, he had contusion on the left temporal are following with unconsciousness. So, he was performed on a craniotomy. Since then, he complained of vertigo with nausea, tinnitus on both sides and disturbance of speech and gait. Results obtained by static function test showed Type III of ARG (Fig. 8, c). Severe irregular writing combined with tremor in nature was



a. A 57-year-old woman with cerebral vascular lesion.
b. A 52-year-old woman with right sided vestibular neuritis.

Fig. 9(a, b). The example in Type Ⅳ of acceleration registrogram.

seen by writing test, though the deviation was not detectable. There was no spontanous or positional nystagmus. Results of caloric test and rotation test showed normal. OKP and result of ETT showed normal.

4) Cases in Type IV.

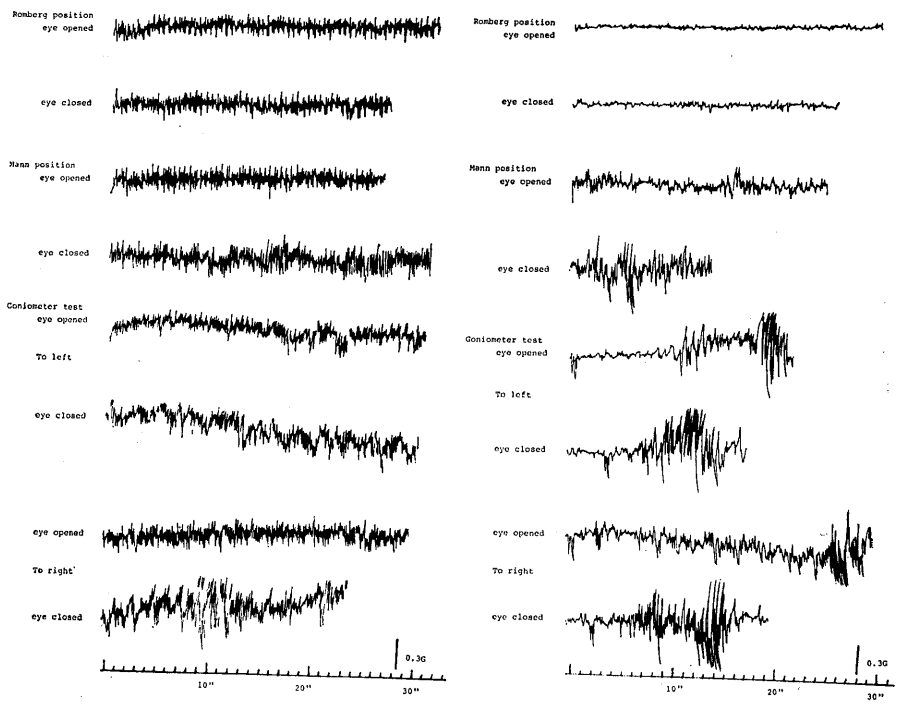
a) A 57-year-old woman with cerebral vascular lesion. She complained of waddling walk with headache and stiff shoulder for about 3 years prior to the examination. She had hypertension. Results obtained by static function test showed Type IV of ARG (Fig. 9, a). The stepping function showed normal. There was no spontanous or positional nystagmus. Results of caloric test and rotation test showed normal responses. OKP and result of ETT showed abnormal.

b) A 52-year-old woman with right sided vestibular neuritis. Two weeks before the examination she had sudden onset of rotatory vertigo accompanied with nausea and vomiting. But she had no tinnitus or hearing loss on both sides. The vertigo was subsided within two weeks. Results obtained by static function test showed Type IV of ARG (Fig. 9, b). The stepping, writing and walking functions showed normal. There was positional nystagmus beating to the left side. Result of caloric test showed canal paresis on the right side, and result of rotation test showed normal responses. Result of ETT showed normal pattern, but OKP showed abnormal.

5) Cases in Type V.

a) A 44-year-old man with cerebral vascular lesion. He had head heavy sensation for last 5 years prior to the examination. Since four months prior to the examination he had vertigo with head heavy sensation. Blood pressure was 154/100 mmHg. Results obtained by static function test showed Type V of ARG (Fig. 10, a). The writing function showed deviation to the right side. There was no spontanous or positional nystagmus. Results of caloric and rotation tests showed hypofunction of both labyrinths. OKP showed abnormal.

b) A 60-year-old man with mercury poisoning. He was fisherman in Tokuyama. He had the first attack of vertigo with nausea and vomiting about 4 years prior to the examination. Since then he had tinnitus on the right side and hearing loss on both sides. He had the third attack 3 years before. He gradually had difficulty in walking because of being unsteady on his feet. He had double vision. Tendon reflexes of the lower extremity were spastic. Results obtained by static function test showed Type V of ARG (Fig. 10, b). The stepping test couldn't be done as skillful as normal, and it was ataxic, but deviation was not observed. There was no positional nystagmus. Result of caloric test showed hypoactive labyrinths on both



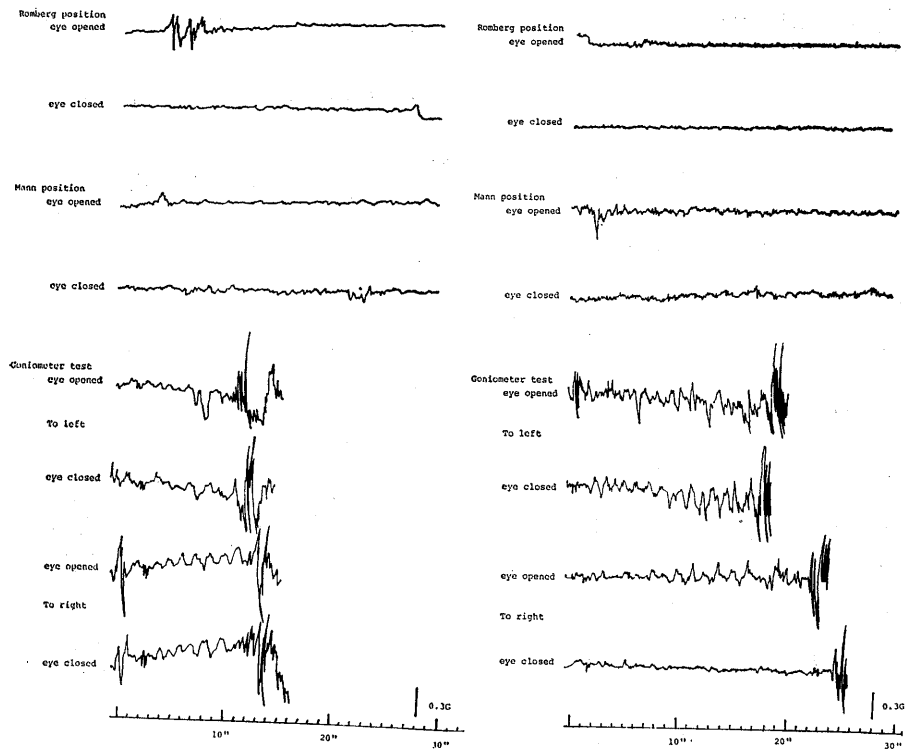
a. A 44-year-old man with cerebral vascular lesion.
b. A 60-year-old man with mercury poisoning.

Fig. 10. (a, b). The example in Type V of acceleraton registrogram.

sides. Result of rotation test showed normal responses on both sides. He had adiadochokinesia on the left side.

6) Cases in Type VI.

a) A 47-year-old man with right sided Meniere's disease. One year prior to the examination he had the first attack of vertigo without accompaning symptoms when he changed his posture quickly. Since four months before the examination, he noticed tinnitus and hearing loss on the right side. Two months before the examination he had the second attack of rotatory vertigo with exacerbated tinnitus and hearing loss on the right side and nausea. Since then he had the similar attacks three times. Results obtained by static function tests showed Type VI of ARG (Fig. 11, a). The stepping function showed deviation to the right side, but writing function showed within normal range. There were spontanous and positional nystagmus beating to the left side in all head positions. Results of caloric and rotation tests presented directional preponderance to the left side. OKP and result of ETT showed normal.



a. A 47-year-old man with right sided Meniere's disease.
b. A 30-year-old woman with congenital nystagmus.

Fig. 11(a, b). The example in Type Ⅵ of acceleration registrogram.

b) A 30-year-old woman with congenital nystagmus. She complained of rotatory vertigo and nausea only when she was very tired. She had no tinnitus or hearing loss. Results obtained by static function test showed Type VI of ARG (Fig.11, b). The stepping and writing functions showed normal. There was pendular spontanous and positional nystagmus. Results of caloric and rotation tests was difficult to point out the end of the induced nystagmus because of large and frequent spontanous nystagmus on recording. OKP and result of ETT showed abnormal.

DISCUSSION

If the human body is in the position of rest, perception of the physical vertical is sufficient. In active movement, the resultants of mass accelerations are necessary for equilibrium. This resultant is the sum of gravity and all the accelerations resulting from the complicated muscular performance. As above mentioned, the human equilibrium of body is

controlled by labyrinthine discharges, proprioceptive impulses from deep tissues, exteroceptive impulse, and visual impulses.

According to Fischer (1956)[6] the labyrinth is of importance to control the equilibrium of body and the cerebellum is the main organ to maintain the antigravity muscular activity. The muscular tonus, particularly of antigravity muscles, is responsible to maintain the upright posture. On the other hand, the proprioceptive and exteroceptive functions are essential to proper correlation of motor acts.

The first neuron of the labyrinth involves the maculae and cristae, the vestibular nerve and ganglion Scarpae. The second neuron involves the central vestibular nuclei and the basal portions of the cerebellum. Secondary fibers pass up and down the brain stem. Cortical centers are considered to be located in the temporal lobe, probably also in the frontal and pariental lobes.

According to Wallenberg (1911)[7] the vestibular apparatus is most important for influencing equilibrium, so that slightest disturbance of this apparatus is sufficient to upset the statics. On the other hand, the ocular lesions have less effect, and the kinesthetic component is the least important.

Anatomical connection with the basal portions of the cerebellum are of special interest to neuroanatomists. The afferent fibers run from vestibular nerve and central nuclei via vestibulo-cerebralis cortex through inferior peduncle to vestibular nuclei; the vestibulo-spinal tracts and the reticular formation of the brain stem. Any lesions within these pathways lead to disturbance of muscular coordination, locomotion, and equilibrium (Fischer in 1956)[6].

Ewald (1907)[8] studied tonic influence of the labyrinth on the muscles and proposed the tonus labyrinthine theory. According to his theory, the impulses emanate from both labyrinths to the muscles of the body and the labyrinth is concerned with tonus of the homolateral extensors and abductors and with that of the contralateral flexors and adductors. Impulses emanating from the labyrinth are transmitted to the centers and central pathways, thus reaching the muscles. Loewenstein and Sand confirmed Ewald's theory by the electro-physical study. They found out action potentials for normal muscles at all times, even rest. The tonus changes with movements of the endolymph.

The problem of tonus was made clear by intensive animal experiments carried out by Magmus and De Kleyn (1924)[9]. From results obtained by experimental studies in cats and rabbits, they classified the labyrinthine reflexs into the following groups:

I). Postural reflexes (Otolith reflexes)
1. Tonic labyrinthine reflexes
2. Labyrinthine righting reflexes
3. Compensatory eye positions
II). Movement reflexes (Semicircular reflexes)
1. Angular movement reflexes
2. Linear movement reflexes
III). Reflexes upon inadequate stimuli
1. Reflexes upon thermic stimuli
2. Reflexes upon galvanic stimuli.

According to Magmus and De Kleyn, postural reflexes is produced by the otolithic organ and depend upon the position of the otoliths with respect to the horizontal plane. Postural reflexes in animal are independent of conscious sensation, because complete decerebrated animals are elicitable.

Tonic labyrinthine reflexes seem to be identical with the postural reflexes of Sherrington. These reflexes enable the individual to bring parts of his body into harmonious postures and to maintain them.

Labyrinthine righting reflexes enable the animal actively to regain its normal posture and to maintain it, so that these reflexes are of most importance to maintain a static posture in animals all the time.

As our starting point we shall take results from animal experiments carried out by Magmus and De Kleyn. According to them, in the animal of unilateral destruction of a labyrinth reflexes tend to bring the head into such a position that the intact labyrinth lies on top, while the destroyed one is underneath. This is the position in which the labyrinthine righting reflexes are at their minimum. With opposite position, their maximum is reached, and the animal exerts all its efforts to regain the minimum position, which is the position at rest.

In testing for righting reflexes in animals, the animal is first lift up, held by its haunches. When the trunk is turned to the side, the animal brings its head in normal position. Next the animal placed on a table in lateral position. When the head is held by the examiner's hand, the animal tried to get up in normal head position.

In human subjects, a normal subject in erect position maintains a condition of normal equilibrium, even if the line of gravity deviates to the periphery of the plane of support, immediately after the line returns to the original course. On the other hand, in cases with a destroyed labyrinth, the patient in erect position does not enable to maintain his equilibrium of the body and falls towards the affected side due to some disturbance of

righting reaction.

With respect to examination of righting reaction, Romberg test, Mann's test, one-leg test and goniometer test are performed clinically. In the present study those tests above mentioned have been used except one-leg test.

Since ancient times attempts have been made to record the results obtained by righting reaction tests (static function tests) in order to take an objective view of equilibrium of human body in static erect posture.

1. Cephalography.

At the beginning, cephalography was used for recording the results of righting reaction tests. In cephalography body movement in erect posture is recorded as a cephalogram on the surface of a flat paper covered with soot, with the sharp needle being attached to the top of the head.

2. Photography (Motion picture).

Motion picture of human body in erect posture has been taken for recording the body movement in righting reaction test. Recently our colleague, Takata studied the human body movement in erect posture by using 16 mm high speed motion picture camera-HYCAM (K 200–Red Lake Laboratory, Ltd). He analyzed the film taken by means of a Filmotion analyzer (Bell & Howell).

3. Electromyography.

It is accepted that electromyography is excellent to analyze the actions of muscular fiber and to determine the characteristics of the reflexes caused by various stimulus. Therefore this method has been used to study the static function and by using this method a number of reports have been presented by many authors.

4. Acceleration registrography.

As already mentioned, acceleration registrography was first described by Kitahara who used unbonded or bonded resistance wire strain-gage type lineal accelerometer as a tranducer which enable to change body movement into electrical potential.

In general, mechanical-electrical transducer enables to change a mechanical quantity into a electrical quantity. Recently by utilizing this principle, in order to record the body movement of human subjects, various kinds of transducer have been used by many investigators. For example, Coats (1973)[10] recorded body sway of human subjects in both lateral and anteroposterior plans a standard precision potentiometer connected to the subjects. In addition, the principle of the strain-gage as a transducer was discovered by Load Kelvin in 1856. Strain-gage has been

applied not only in measuring the strain and stress of material under test, but in constructing many kind of transducers in technology. Since then strain-gage uor example, blood and intra-ocular pressure have been measured.

Since a decade we have been using an unbonded or bonded resistance wire strain-gage type linear accelerometer as a transducer for recording the righting responses obtained by static function tests in Dept. of Yamaguchi University Hospital. In our experiences we are able to say, beyond any doubt, that this accelerometer is most aviable to record body movements obtained by static function tests.

SUMMARY

Righting responses in erect posture were tested in 220 patients with complaining vertigo by means of static function tests, such as Romberg test, Mann's test and Goniometer test. Righting responses (body movements) were recorded by acceleration registrography. Acceleration registrogram (ARG) obtained by the tests were divided into six types by method of Honjo and Ishihara.

Sixty nine patients (31.4%) belonged to type I, presenting normal righting response. Eighty patients (36.4%) belonged to type II, 19 patients (8.6%) to type III, 37 patients (16.8%) to type IV, 5 patients (2.3%) to type V, and 10 patients (4.5%) to type VI.

In the majority of patients, the more the righting responses are discribed, the more incidence of abnormal responses in vestibular and optokinetic nystagmus increase.

Patients with an identical diagnostic category do not belong the same type, but divide into a few types.

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