Caloric Stimulation on the Labyrinth

Toru SEKITANI

Department of Otolaryngology,
Yamaguchi University School of Medicine.
Ube, Japan

It is to the credit of Brown-Sequard to have demonstrated in 1860 that caloric stimulation elicits labyrinthine symptoms. Reports in the literature concerning the caloric stimulation on the labyrinth have been published by a number of investigators up to date. It is, however, generally accepted that Barany (1905) was the first to introduce caloric stimulation into clinical test of the labyrinth.

Although the caloric stimulation of the labyrinth is by no means a physiological procedure it happens to be one of the most used clinical methods of testing th e superior part of the labyrith, because it enables to stimulate each labyrinth separately. From physical point of view, the principle of caloric stimulation depends upon the convection current of the endolymph. The induction of a temperature change at one point of the lateral semicircular canal kept in the vertical position induces a convection current of the endolymph. The direction of the temperature gradient determines the direction of the induced convection current which acts upon sensory receptor. This leads to caloric nystagmus.

Many methods of caloric stimulation in both clinical and experimental fields have been described since the time of Barany.

Over a 10 years period, 1959 to 1969, the following studies on caloric stimulation of the labyrinth were carried out at the Dept. of Otolaryngology Yamaguchi University Hospital.

Tahara in 1959[1] studied bilateral caloric stimulation in 171 normal healthy subjects and 124 patients with complaining vertigo. In normal subjects their ages ranged from 16 to 35 years and sex distribution had no preferance. A series of 124 consecutive patients with vertigo were examined at our clinic in 1955 to 1958. Their ages ranged from 14 to 74 years and their sex distribution was 81 males and 43 females.

In order to perform bilateral calorization an apparatus illustrated in Fig. 1 was devised by Tahara. The subject was placed in a recumbent position with the head elevated 30° above the horizon, the so-called optimum position for stimulating the lateral semicircular camal. Calorization was carried out by means of 1,500 cc (in each ear) of water at 10° or 40° C for 6 minutes.

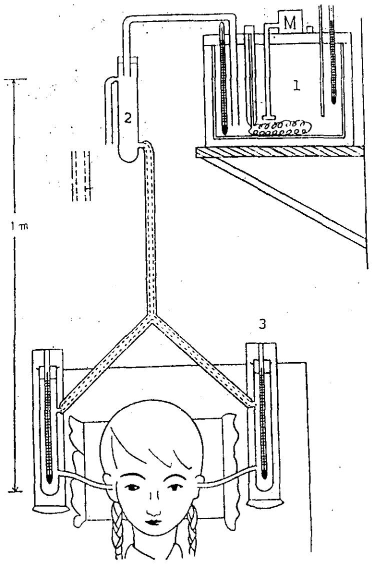

Fig. 1. 1. Thermostat 2. Equipment of overflow 3. Thermometer

Results from normal subjects.

1. Calorization, using water at 10° C, elicited vertical nystagmus in 100 percent of subjects. The latent period of nystagmus ranged from 108 to 29 (average 58.1±2.40) seconds and the duration time ranged from 473 to 93 (average 370.3±19.97) seconds.

2. Calorization, using water at 20° C, elicited vertical nystagmus in 89.1 percent of subjects. The latent period of nystagmus ranged from 123 to 35 (average 74.9±1.69) seconds and the duration time ranged from 460 to 120 (average 335.8±7.36) seconds.

3. Calorization, using water at 30° C, elicited vertical nystagmus in 18.2 percent of subjects. The latent period of nystagmus ranged from 195 to 61 (average 115.4 ± 12.25) seconds and the duration time ranged from 373 to 208 (average 295.0±152.35) seconds.

4. Calorization, using water at 40° C, elicited no nystagmus.

5. when the head of subjects was changed from the aforementioned so-called optimum position into any other positions, there was no nystagmus in all subjects.

6. After disappearing vertical nystagmus, if the head of subjects was tilted to right or left 90 degrees, rotatory nystagmus towards the down sided ear was present. After disappearing the aforementioned rotatory nystagmus, if the head of subjects was tilted to right or left 180 degrees,

rotatory nystagmus towards the opposite side was present.

Results from patients with vertigo.

One hundred and twenty-four patients with vertigo in this study consisted of 51 Meniere's disease, 11 brain tumor, 14 labyrinthitis, 8 labyrinthine lues, 16 head trauma, 4 acoustic trauma, 10 streptomycin poisoning and 10 deafness.

Results obtained were classified into three groups: 1) horizontal nystagmus is present in 62 patients (50 percent); 2) no nystagmus is present in 49 patients (39.5 percent); 3) vertical nystagmus is present in 13 patients (10.4 percent). Group 1. In patients showing horizontal nystagmus, when using cold water the direction of nystagmus was toward the more affected side, and when using hot water the direction of nystagmus was toward the less affected side. Group 2. In patients showing no nystagmus there was no difference of response on both labyrinths. Group 3. In patients representing vertical nystagmus, when using cold water vertical nystagmus was present whereas no vertical nystagmus was present by using hot water.

Miyake in 1960[2] studied caloric response elicited by a large quantity of water in 62 normal healthy subjects and 80 patients with vertigo. In normal subjects their ages ranged from 16 to 48 years and sex distribution had no preferance. A series of 80 consecutive patients with vertigo were tested at our clinic in 1955 to 1958. Their ages ranged from 15 to 64 years. and they consisted of 54 males and 26 females. For carrying out caloric

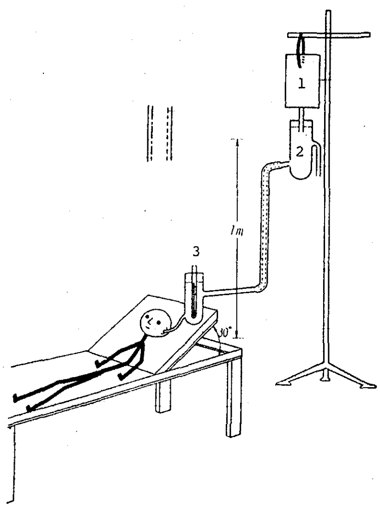

Fig. 2. 1. Thermostat 2. Equipment of overflow 3. Thermometer

stimulation a constant water pressure thermostat was used as shown in Fig. 2. The subject was placed in a recumbent position with the head elevated 30° above the horizontal, the so-called optimum position for stimulating the lateral semicircular canal. Caloric stimulation was performed on by means of 3,000 cc of water at 30° C for 12.0 minutes. Visual response was excluded by use of Frenzel's glasses.

Results from normal subjects.

The aforementioned large quantity calorization elicited the following nystagmus in 100 percent of normal subjects. That is, after latent period the nystagmus towards the opposite side (The first phase of nystagmus) was present which lasted during calorization and still continued after stopping calorization. After disappearing the first phase of the nystagmus a pause was seen. After that pause the second phase of nystagmus represented towards the stimulated side. Latent period ranged from 13 to 20 sec (average 15.5±0.25) in the right ear and from 13 to 21 sec (average 15.7±0.35) in the left ear. After stopping calorization the first phase of nystagmus ranged 25 to 66 sec (average 46.6±2.68) in the right ear and from 30 to 72 sec (average 50.8±1.89) in the left side. The pause was lasting for 2.4 sec in the right side and 2.0 sec in the left side. The second phase of nystagmus ranged from 38 to 97 sec (average 67.2±3.32) in the right side and from 45 to 98 sec (average 67.8±2.51).

Results obtained by using non e constant water pressure thermostat were not differ from the aforementioned results in statistical value.

Results from patients with vertigo.

Of 80 patients with vertigo, the same patterns of nystagmus to that in normal subjects were seen in 47 patients (58.75 percent). The remainders represented the following patterns of nystagmus. In 31 of 80 patients (38.7 percent), the second phase of nystagmus was not seen. One patient represented no nystagmus and other one showed the second phase of nystagmus during stimulation.

Nakamura in 1960[3] studied caloric stimulation in normal rabbits.

1. Unilateral calorization in different head postures.

Thirty healthy rabbits, weighing 2 kg, were used. The animal was placed in a horizontal table with fixing the head, trunk and four legs firmly. An equipment illustrated in Fig. 3. was devised which enable to change posture of the animal over both bitemporal and sagittal axes (Fig. 4). Calorization, using 5.0 cc of water at 10° C for 5 seconds, was applied to provoke nystagmus.

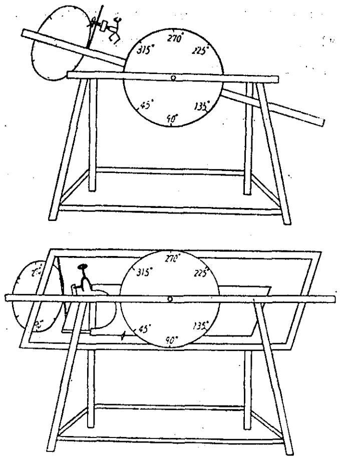

Fig. 3. An equipment for posture changing in animal.

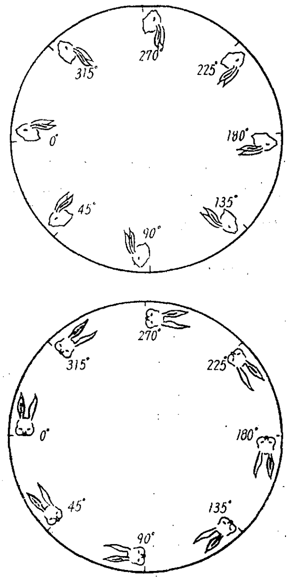

Fig. 4. Postures of the animal over a bitemporal axis and over a sagittal axis.

Latent period and duration of the nystagmus elicited by the calorization in various postures over a bitemporal axis are shown in Table 1. In these postures over a bitemopral axis, horizontal nystagmus toward the opposite side was seen in the postures, 0, 270 and 315 degrees; horizontal nystagmus toward the stimulated side was seen in a posture, 45 degrees,

Table 1. Latent period and duration of the nystagmus elicited by the calorization in various postures over a bitemporal axis in 30 normal rabbitts.

Posture	Latency			Duration		
0°	9.8	l	10.2	54.2	l	52.8
		r	9.4		r	55.6
45°	6.5	l	7.3	51.2	l	53.1
		r	5.6		r	49.2
90°	9.7	l	9.2	77.8	l	80.2
		r	10.1		r	75.4
135°	10.7	l	11.3	48.3	l	49.2
		r	10.2		r	47.3
180°	10.0	l	10.1	61.3	l	60.4
		r	9.8		r	62.2
225°	9.4	l	9.6	53.5	l	52.8
		r	9.2		r	54.1
270°	5.2	l	5.3	50.9	l	50.6
		r	5.1		r	51.3
315°	5.3	l	5.4	53.8	l	53.2
		r	5.1		r	54.3

(Second)

Table 2. Latent period and duration of the nystagmus elicited by the calorization in various postures over a sagittal axis in 30 normal rabbits.

Posture	Latency			Duration		
0°	9.8	l	10.2	54.2	l	52.8
		r	9.4		r	55.6
45°	8.9	l	9.5	29.9	l	21.7
		r	8.4		r	38.2
90°	7.3	l	8.5	54.0	l	42.5
		r	6.1		r	65.5
135°	7.8	l	8.3	34.9	l	27.6
		r	7.3		r	42.3
180°	10.0	l	10.1	61.3	l	60.4
		r	9.8		r	62.2
225°	7.9	l	6.8	42.5	l	48.4
		r	8.9		r	36.5
270°	4.6	l	4.2	65.2	l	68.2
		r	4.9		r	62.1
315°	6.9	l	6.2	58.3	l	62.1
		r	7.5		r	53.4

(Second)

rotatory nystagmus toward the stimulated side was seen in the postures, 90, 135 and 180 degrees, and rotatory nystagmus toward the opposite side was present in a posture, 225 degrees.

Latent period and duration of the nystagmus elicited by the calorization in various postures over a sagittal axis are illustrated in Table 2. In these postures, horizontal nystagmus toward the oppositeside was seen in the postures, 0, 45 and 315 degrees, horizontal nystagmus toward the upper sided ear was present in the postures, 90, 135, 225 and 270 degrees, and rotatory nystagmus toward the stimulated side was seen in a posture, 180 degrees.

2. Unilateral calorization elicited by a large quantity of water in a posture of 270 degrees over a bitemporal axis.

Twenty healthy rabbits, weighing 2 kg, were used. The animal was placed in a table with fixing the head, trunk and four legs. In order to irrigate, an apparatus shown in Fig. 5 was devised. Calorization, using 3,000 cc of water at 10° C for 13 minutes, was applied to elicit nystagmus.

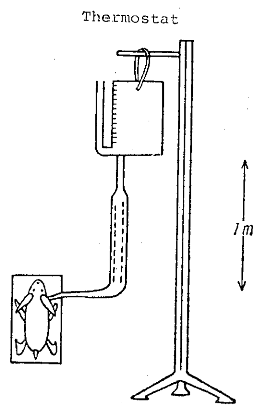

Fig. 5.

In 13 of 40 ears (32.5 percent) the second phase of nystagmus was present. In 24 of 40 ears (60.0 percent) only the first phase of nystagmus was seen. The remainders showed that the third, fourth and sixth phases were present in each only one ear.

3. Bilateral calorization in different head postures.

Thirty-five healthy rabbits, weighing 2kg, were used. The animal was placed in the same manner to that of the unilateral calorization mentioned in chapter 1. In order to carry out bilateral calorization, an apparatus

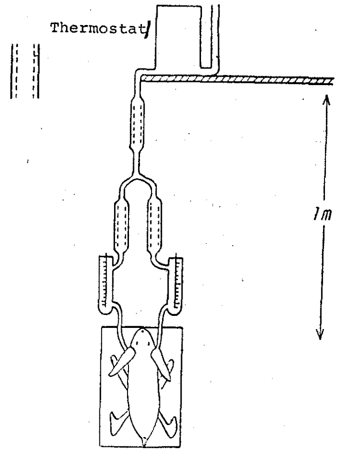

Fig. 6.

illustrated in Fig. 6 was used.

Calorization, using 500 cc (in each ear) of water at 10° C for 2 minutes, was applied to provoke nystagmus.

Direction, latent period and duration of the nystagmus elicited by the calorization in various postures over a bitemporal axis are shown in Table 3. Direction, latent period and duration of the nystagmus elicited by the calorization in various postures over a sagittal axis are revealed in Table 4.

4. Bilateral calorization by using different temperatures.

Twenty healthy rabbits, weighing 2 kg, were used, The animal was

Table 3. Direction, latent period and duration of the nystagmus elicited by the bilateral calorization in various postures over a bitemporal axis in 35 normal rabbits.

Posture	Direction	Latency	Duration
0°	↑	45.8	122.1
45°	(−)	(−)	(−)
90°	(−)	(−)	(−)
135°	(−)	(−)	(−)
180°	↷↶	21.3	113.8
225°	↷↶	11.2	137.8
270°	↑	35.6	136.8
315°	↑	39.8	92.3

(Second)

Table 4. Direction, latent period and duration of the nystagmus elicited by the bilateral calorization in various postures over a sagittal axis in 35 normal rabbits.

Posture	Direction	Latency	Duration
0°	↑	45.8	122.1
45°	→	16.8	109.7
90°	→	14.1	184.3
135°	→	11.9	159.8
180°	∩↓∩	21.3	113.8
225°	←	9.7	209.8
270°	←	8.4	195.2
315°	←	14.4	109.5

(Second)

managed in the same manner to that in chapter 2. Calorization, using 1,500 cc (in each ear) of water at 10°, 20°, 30° and 40° C for 6 minutes, were applied to elicit nystagmus.

Vertical nystagmus represented by bilateral calorization, using water at 10° and 20° C in 100 percent of animals, whereas calorization, using water at 30° and 40° C, elicited no nystagmus.

Ito in 1969[4] studied the relation between optokinetic and caloric nystagmus in normal subjects. Thirty young healthy subjects tested consisted of 15 males who are medical students and 15 females who are nursing school students. The subject was placed in a recumbent posture with the head elevated 30° above the horizontal. Optokinetic stimulation was given by a rotatory drum, 150 cm in diameter, 80 cm in height, with a vertical rotatory axis and twelve black vertical strips 5 cm wide outside as shown

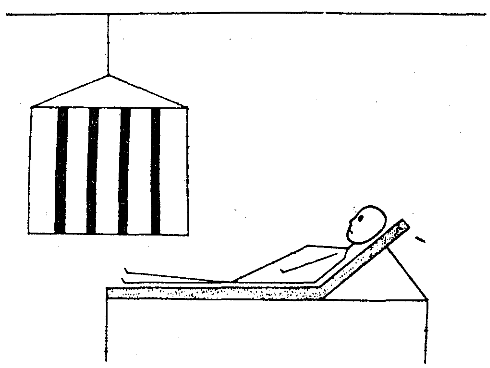

Fig. 7. Posture of the subject and equipment of optokinetic nystagmus.

in Fig. 7. The drum was placed 85 cm in front of the subject and was rotated at angular speed of 60° and 36°/sec. Calorization, using 200 cc of water at 0°, 5°, 10° 15° and 20° C for 10 seconds, was applied to elicit caloric nystagmus.

The following results were obtained. 1. When the quick phases of optokinetic and rotatory nystagmus were in the same direction, frequency and slow phase of the nystagmus were increased due to an influence of vigorous caloric response. 2. When the directions of both nystagmus were reverse, frequency and slow phase of the nystagmus were decreased due to an influence of vigorous caloric response. In addition, direction of the nystagmus was classified into three types:
1) direction of the nystagmus is identical with caloric one;
2) direction of the nystagmus is identical with optokinetic one;
3) direction of the nystagmus is irregular.

Inoue in 1960[5] carried out experimental studies on cold air stimulation. An equipment illustrated in Fig. 8 was used for cold air stimulation. Stimulation, using 0.05, 0.1 and 0.2 kg/cm² of air pressure at 0° C for 15 and 30 seconds, was applied to elicit response (nystagmus).

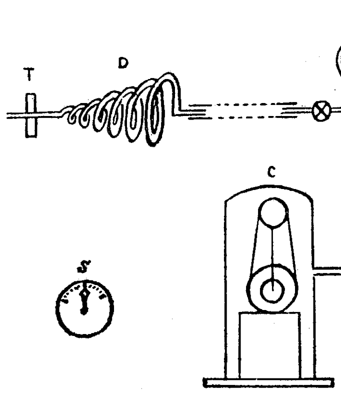

Fig. 8. An equipment for cold air stimulation.
T. Thermometer, D. Equipment of Sir Dundas Grand, P. Manometer, B. Valve, C. Compressor, S. Slidac.

1. Twenty-seven normal healthy guinea-pigs were used. Latent period and duration of the nystagmus were shown in Table 5. It will be seen in Table 5 that latent period was identical without respect of different air pressure or stimulation time, whereas the more air pressure or stimulation time increased, the more duration time of nystagmus prolonged in normal animals.

2. Fifteen adult guinea-pigs with bilateral ear drums perforation were used. Mean value of latent period was about 5 seconds which was identical without respect of different air pressure or stimulation time, and the more air pressure or stimulation time increased, the more duration of nystagmus (21 to 68 sec) prolonged.

3. Nine adult guinea-pigs with removal of the stapes were used. Results obtained were almost the same to that of animals perforated ear drum.

4. Fourteen adult guinea-pigs performed on fenestration on the lateral semicircular canal were used. Latent period was not seen, and duration of the nystagmus was 73.03+4.04 secods by stimulation for 15 seconds and was 95.07+5.43 seconds by stimulation for 30 seconds.

Inoue in 1960[6] studied cold air stimualtion in normal subjects and patients with ear drum perforation and vestibular disturbance. In order to perform cold air stimulation, an apparatus was used which was improved on Sir James Dundas Grand's cold air instrument. Stimulation, using 0.05 kg/cm^2 of cold air at 10° C for 15 and 30 seconds, was applied to provoke nystagmus.

1. One hundred and seventy-one normal healthy subjects were used. Their ages ranged from 19 to 56 years. Latent periods ranged from 12 to 27 (average 19) seconds without respect of stimulation time (15 or 30 sec). Durations of nystagmus ranged from 66 to 145 (106.07±1.38) seconds by stimulation time for 15 seconds and 83 to 251 (133.77±1.98) seconds by stimulation time for 30 seconds.

2. Forty-two patients with middle ear disease were examined.

a. In 10 cases with middle ear catarrh, latent period and duration of nystagmus was identical with those of normal subjects.

b. Of 13 cases with a small perforation of the ear drum with discharge, 8 cases represented normal latent period and duration of nystagmus, 3

Table 5. Mean value of latent peri od and duration of nystagmus elicited by cold air stimulation in 27 normal guinea-pigs.

Air pressure	stimulation time (seconds)	Latent period (seconds)	Duration of nystagmus (seconds)
0.05	15	7.15±0.49	30.66±1.2
〃	30	7.38±0.25	49.35±1.47
0.1	15	7.26±0.36	33.40±0.59
〃	30	7.93±0.42	48.20±0.34
0.2	15	7.03±0.75	41.16±0.46
〃	30	7.10±0.26	55.70±1.82

cases showed prolonged duration of nystagmus and 2 cases showed decreased duration of nystagmus.

c. Of 9 cases with a large perforation of the ear drum, the majority of cases represented decreased latent period and prolonged duration of nystagmus.

d. Of 8 cases with postoperative ear condition, 5 cases represented short latent period and prolonged duration of nystagmus, and 3 cases revealed the same response to that of normal subjects.

3. One hundred and eleven patients with vestibular disturbances were examined. Their diagnostic categories were as follows: 21 congenital deafmutism, 15 acquired deafmutism, 40 Meniere's disease, 3 labyrinthine lues, 12 streptomycin poisoning, 8 headtrauma, 3 brain tumour, 1 acoustic tumour, 3 labyrinthitis and 5 vestibular neuronitis. Results obtained represented the same responses to that of caloric stimulation by means of cold water.

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