Clinical Significance of Galvanic Body-Sway

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Hitzig, E. (1871)[1] was the first to describe the galvanic nystagmus obtained by an electric current sent through the head of a subject. This nystagmus was recognized as the vestibular apparatus in origin by many investigators. For example, Ewald (1907)[2] studied an animal experiment with pigeons and confirmed that galvanic current stimulates the endings of the vestibular nerve but does not act on the vestibular sense organ proper. Marx (1911)[3] experimented with guinea pigs. He destroyed all the semicircular canals and obtained a normal galvanic response. Finally he destroyed the entire labyrinth and still he found a positive galvanic reaction.

In clinical experiences a few authors reported similar observation in patients to the results obtained by Marx. Neumann (1907)[4] reported a case performed a complete resection of the labyrinth and proved on vestibular tests that the caloric, rotatory and mechanical reactions were negative, while the galvanic response was positive. These results in patients led otologists to the thought that the galvanic response is of importance to make a differentiation between labyrinthine and vestibular lesions. Brunner (1932)[5] proved by using combined galvanic and caloric test that anode as well as cathode can stimulate the vestibular nerve fibers. Steinhausen, in his famous experiment, revealed that galvanic current is not able to elicit a deflection of the cupula in the semicircular canal. Dohlmann (1935)[6] believed in his experiments that the electrical current acts upon the vestibular ganglion in the internal auditory meatus.

As to the explanation of the opposite effects of anodal and cathodal stimulus, Barany (1906)[7] believed that anodal current decreases the labyrinthine excitability, while cathodal current increases it in a qualitative difference. On the other hand Wilson and Pick (1915)[8] canfirmed in quantitative difference. A weak stimulus (anode) excites certain fibers of the vestibular nerve producing nystagmus to the opposite side, whereas a strong stimulus (cathode) elicits a nystagmus to the same side.

As the vestibular function test, clinically the galvanic test is performed in order to differentiate lesions of the labyrinth from affections of the vestibular nerve. Thus this test is indicated in cases in which the vestibular response under caloric and rotatory stimulation decreases or is absent, so that it becomes necessary to know whether or not the galvanic response can be elicited. From the results obtained by galvanic test, a positive response shows a labyrinthine lesion and a negative reaction prove a vestibular nerve disturbance (retrolabyrinthine in origin). Brunner (1932)[5] utilized the galvanic test to differentiate spontaneous nystagmus in labyrinthine diseases from central vestibular lesions, because the central can be influenced by galvanic stimulation, notwithstanding the peripheral proves no change.

We come now to review the galvanic test methods. Galvanic test methods carried out clinically in recent years can be classified into the following three methods: 1) unipolar test; 2) bipolar test; and 3) double electrode test. Nstagmus elicited by galvanic stimulation is a horizontal-rotatory or a rotatory in nature and the direction of quick phase is towards the same to galvanic current. Since the electric current flows from the anode to the cathode, the galvanic nystagmus is directed towards the side of the applied cathode.

The above mentioned nature and direction of the nystagmus are independent of the head position in subjects, so that the galvanic stimulation dose not act upon the semicircular canal but rather upon the vestibular nerve.

Direction of the falling reaction or body-sway elicited by galvanic stimulation is towards the anodal electrode, that is to say, the direction of slow phase of nystagmus. Electrodes used in galvanic stimulation are matals in a form of a small round or a large square. In order to lessen the contact resistence between electrode and the skin as far as possible, the electrode is soaked in a saline solution.

1). Unipolar test. A stimulating electrode is applied on the vicinity of the ear (the mastoid or tragus) and the indifferent electrode is placed on the neck or forearm. On closing the electric circuit, nystagmus occurs at 10 to 16 milliampers. If the anode is a stimulating electrode, the nystagmus is directed towards the opposite side and body-sway occurs towards the stimulating side. On the other hand if the cathode is used as a stimulating electrode, nystagmus elicits towards the stimulating side and body-sway occurs towards the opposite side.

2). Bipolar test. An electrode is placed on the vicinity of each ear (one is anodal and the other is cathodal), so that the electric current is sent through the head. In this test, nystagmus is elicited towards the cathodal electrode at 2 to 5 mA. and body-sway towards the anodal electrode at 1.0

to 1.5 mA.

3). Double electrode test. The stimulating electrode is split into two electrodes applied on the vicinity of each ear, and the indifferent electrode is placed on the neck or forearm. When the vestibular response in each side becomes neutralized, no nystagmus or body-sway occurs. On the other hand if the vestibular response is different in both sides, nystagmus or body-sway elicits. In this condition, if the stimulating electrode acts upon as anode, the body-sway is directed towards the greater irritability of the labyrinth and the nystagmus towards the side of the labyrinth with the lesser irritability; when the cathods, the body-sway is directed towards the side of the labyrinth with the lesser irritability and the nystagmus towards the greater irritability of the labyrinth.

As mentioned before, although there are dissenting opinions, it is generally accepted by many authors that the galvanic stimulation does not act upon at the labyrinth but at the retrolabyrinthine locations, such as Scarpa's ganglion, the vestibular nerve and nuclei. From this reason if the galvanic stimulation could be developed in clinical test, it seems to provide a mean of distinguishing between labyrinthine and retrolabyrinthine lesions. Since long years many authors have tried to develop clinical galvanic test which have almost always been based upon the nystagmus. However, with bipolar as mentioned above, galvanic stimulation, approximately 5.0 mA and with unipolar stimulus about 10.0 mA are necessary to elicit nystagmus. At this current level, the subjects always complain of discomfort and pain.

As far as the galvanic body-sway responses is concerned, there have been a few studies, both animal and human, in the literature. Dix, et all (1949)[9] used galvanic responses to study the effects of streptomycin poisoning. Kuhnke (1950)[10] recorded the galvanic body-sway response in normal subjects. Cervantes (1952)[11] studied quantitating the galvanic body-sway response by using a graduated wooden are placed above the subject's head. Recently Coats (1969 and 1973)[12],[13] investigated galvanic body-sway responses using a standard precision potentiometer in detail.

In this paper, we propose to report the results of galvanic body-sway response using medical data processing computer in a group of normal subjects and a small series of cases with labyrinthine and vestibular nervous lesions.

METHODS AND MATERIAL

1. Test subjects.

40 normal subjects and a few patients were studied. The normal group of subjects consisted of 20 males and 20 females. They were all medical and nursing students at our university. Their ages ranged from 18 to 25 years, with an average of 22 years.

All normal subjects had a history of normal hearing and equilibrium, and had no other evidence of normal hearing and abnormality. All had normal vestibular and audiometric response.

Four patients studied consisted of each one case of Meniere's disease, vestibular neuritis, deafmute, and cerebellopontine angle tumour.

2. Instrumentation for recording body sway.

Body sway in both the lateral and anteroposterior planes was recorded using the instrumentation diagramed in Fig. 1. In order to measure body sway of subjects, two accelerometers of which directions of action are lateral or anteriorposterior were used. Two accelerometers were fixed on the top of a light helmet which was fastened firmily to the head of the subjects, so that they inclined when the subjects body swayed. In this way it makes possible to record the subject's body sway in the lateral and anteroposterior planes simultaneously. Mechanical characteristics of the accelerometer is given in the previous report by Tanaka.[14]

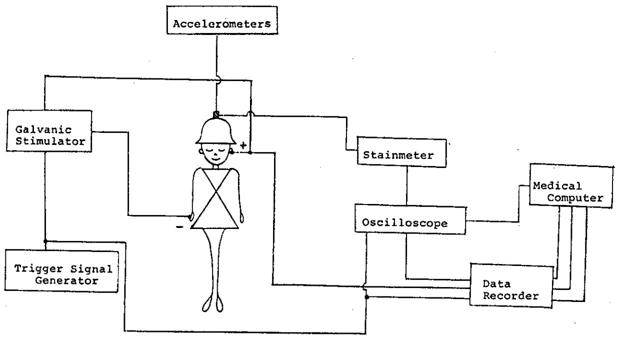


Fig. 1. Block diagram of the Instruments in the Present study

Two accelerometers were connected with two dynamic strain meters so that the output of these instruments was voltage change which was proportional to the movement of the subject's body. Mechanical characteristics of the strain meter is given in the previous report by Tanaka.[14]

The output from the strain meters was observed with oscilloscope and simultaneously recorded on a magnetic recording tape with data-recorder.

In order to process and analyse data, a medical data processing computer was used. As the condition of this instrument, program of the computer was set for calculating average of each component of the head movement, of which the first channel was for lateral and the second one was for the anteroposterior plane of the head movements. One of the remaining channels was used for marker of stimulation. In this program, the address number of each channel will be 256. Of the computer's caribration, the input power is arranged so that 150×10^{-6} strain becomes four graduations on Brown tube screen. Trriger mode was set on EXT, and was prepared to begin work at the trigger sign recorded in the magnetic recording tape of data-recorder. In this procedure, average data was obtained from the eight trails. Because it takes relatively long time of about 25 seconds for one recording of this galvanic test, the authors closed the program of eight times addition for lessening the fatigue of the test subjects. So it takes about three minutes to finish the test for each subject. Main mechanical characteristics of medical data processing computer is given in the previous report.[14)]

a. Electrodes. Stimulating electrode was made of silver, 3 cm in diameter, which was fixed with a rubber band at the skin of postauricular area on each side. A standard electrocardiogram plate electrode, placed on the contralateral forearm, served as the indifferent electrode. with this arrangement, resistance between the stimulating and indifferent electrodes was usually between 3,000 and 5,000 ohms.

b. Current generator.

As a galvanic stimulator, an electronic stimulator was used. Another electronic stimulator was also used for a generator of trigger signal at intervals of 25 seconds, triggering the galvanic stimulator and oscilloscope action. The delay time was set at the galvanic stimulator to cause stimulating current in one second after trigger's operation. The electric current caused by each stimulator was recorded to the data recorder as well as the signals of the head sway response.

3. Test procedure.

Galvanic stimulation was delivered by anodal unipolar and double electrodes. In this study we used stimulus at 0.6 mA, for 10 sec, with interval of 15 sec. All responses were obtained while the subject was standing with his arms at his sided, his feet parallel and touching, and his eyes closed.

It will take about three minutes for one series of eight times stimulations, so that we arranged to give a rest of five minutes at least for each subject sitting on the chair after every examination.

In the body sway recording, upwards wave deflection of oscilloscope corresponds to sway to the right side in the lateral plane and as to in the anteroposterior plane upwards wave deflection corresponds to sway to the backwards.

RESULTS

1. The normal galvanic body-sway responses.

When galvanic current of positive polarity is applied to one ear, the body sways towards the stimulated side. When the current is removed, the body sways away from the stimulated ear.

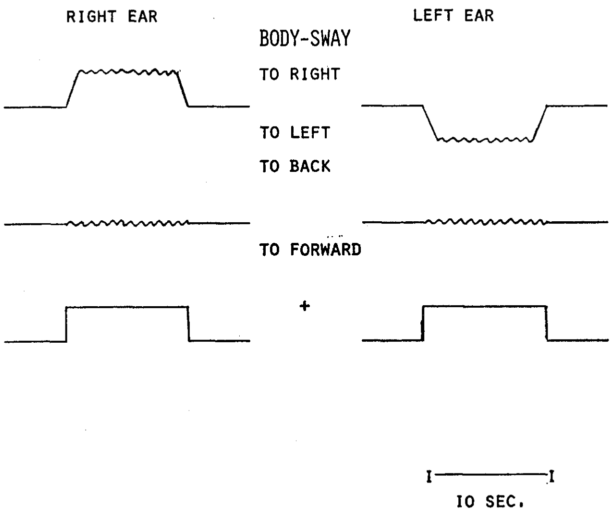
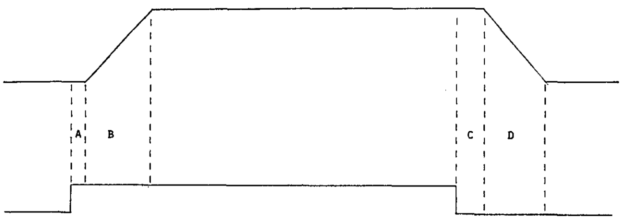


Fig. 2. Galvanic Body-Sway in normal subjects unipolar anodal stimulation



Unipolal anodal stimulation at 0. 6 mA for 10 sec.

A : 0. 1−0. 8 sec. 0. 36±0. 15 sec. C : 0. 4−1. 0 sec. 0. 55±0. 18 sec.
B : 1. 0−3. 0 sec. 1. 75=0. 57 sec. D : 0. 7−2. 7 sec. 1. 60±0. 47 sec.

Fig. 3. Galvanic Body Sway responses at onset and cutoff of the stimulus in normal subjects

Fig. 2 shows galvanic body-sway responses in all of our normal subjects stimulated by anodal electrode on one ear. For example, when the right ear is stimulated the body sways to the right side, and when the left ear is stimulated the body sways to the left side in lateral plane. As to the anteroposterior plane, there is no regular pattern in this procedure. In the majority the body rocks slightly back to forwards except in a few subjects the body sways slightly to the backwards or forwards.

As far as body-sway due to galvanic stimulation is concerned, it seems to be important to analyse the responses at onset and cutoff of the stimulus. As shown in Fig. 3, there was a latent period from the onset of the galvanic stimulus to occurrance of body-sway. It ranged from 0.1 to 0.8 seconds, and the averge value and standard deviation were 0.36+0.15 sec. And then after some latent period the body swayed and retained its deviation. During the body-sway, the time spent amounted to 1.0–3.0 seconds and the average value and standard deviation were 1.75+0.57 sec. At the cutoff of the stimulus, there was also a latent period until occuring the body-sway. It ranged from 0.4 to 1.0 seconds and the average value and standard deviation were 0.55±0.18 sec. During the body-sway due to cutoff of the current, the time spent amounted to 0.7–2.7 sec., and the average value and standard deviation were 1.60+0.47 sec.

Behavior, while the current is on and after off, seems to be classified into three groups: 1. the body retains its deviation so that the cutoff brings it back to the midline; 2. the body comes back to the midline so that the cutoff carries it away from the midline in the opposite direction; 3. the body does not come back to th midline so that the cutoff does not bring it back to the midline (Figs. 4 and 5).

In 40 normal subjects of the present study, we found out that 33

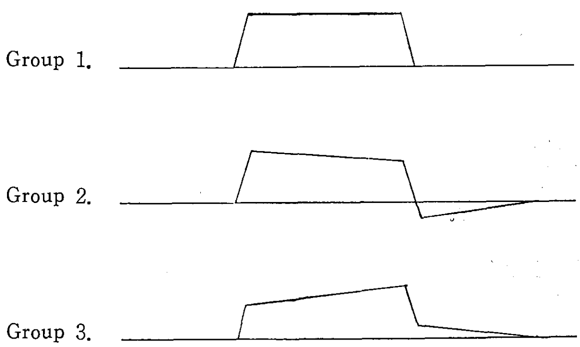


Fig. 4. Patterns of galvanic Body-Sway in normal subjects

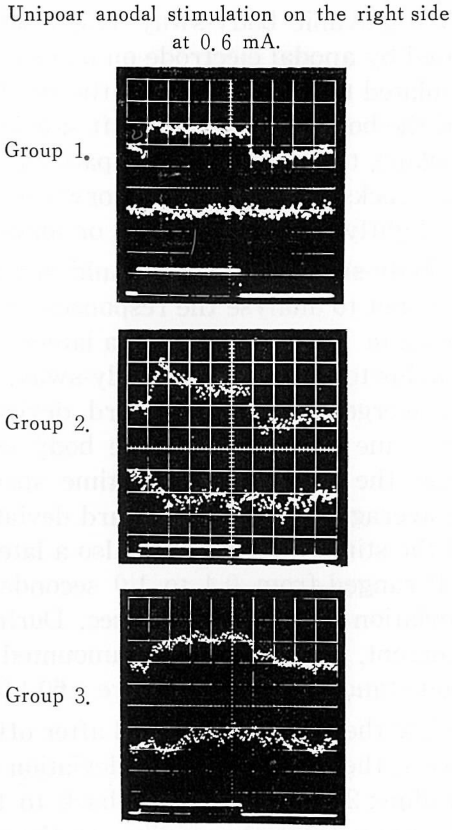


Fig. 5. Patterns of galvanic Body-Sway in normal subjects

showed the same group on each side: 17 in group 1; 12 in group 2; and 4 in group 3; and 7 revealed the different groups on both sides; 5 in grop 1 and 2; 1 in group 1 and 3; and 1 in group 2 and 3.

Fig. 6 shows a representative example of the original waves on oscilloscope obtained by unipolar anodal stimulation on the right side of the same normal subject eight times. It will be seen that each wave shows different body-sway in spite of the same stimulation. Fig. 7 shows the average wave of eight waves shown in Fig. 6 obtained by using a medical data processing computer.

As shown in Fig. 8, when galvanic current of positive polarity is applied to the vicinity of the one ear, that is to say, unipolar anodal stimulation, in normal subjects, the body sways towards the stimulated side, on the other hand if galvanic current is applied to both sides simultaneously, that is to say double galvanic stimulation, no body-sway is

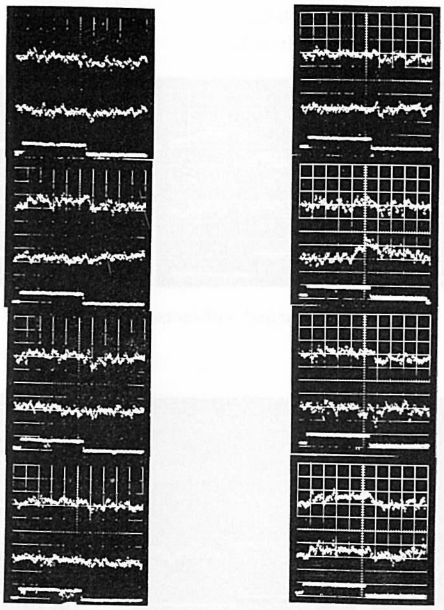


Fig. 6. Eight figures show factual waves of Body-Sway elicited by unipolar anodal stimulation on the right side in the same normal subject.

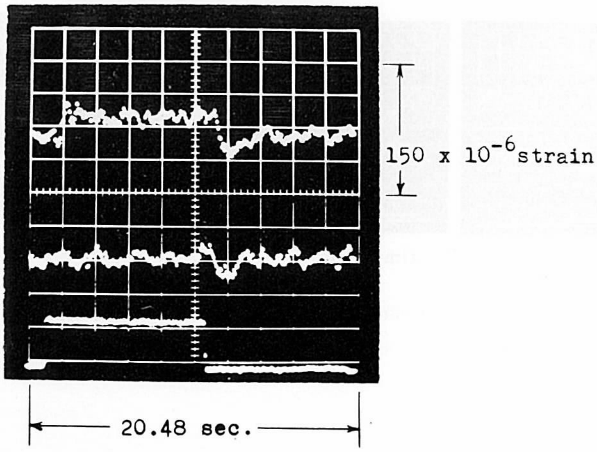


Fig. 7. The average wave in eight figures obtained by using medical data processing computer.

Unipolar anodal stimulation Double anodal stimulation
Right side Left side

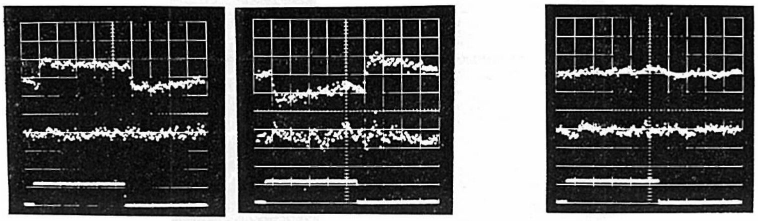
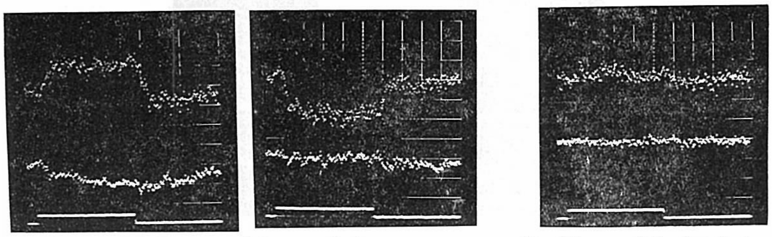
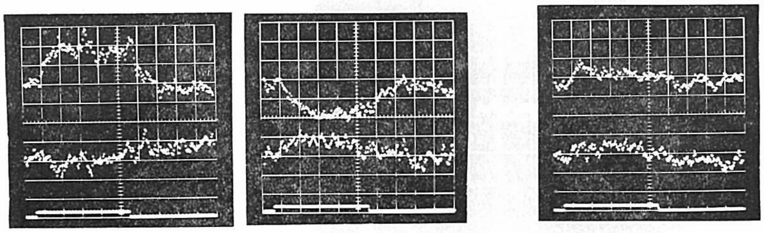


Fig. 8. Galvanic Body-way in normal subjects at 0.6 mA for 10 sec.



Unipolar anodal stimulation Double anodal stimulation
Right side Left side
Case 1. A 35- year-old woman with left sided Meniere's disease

Fig. 9. Galvanic Body-Sway responses in patients at 0.6 mA for 10 sec.



Unipolar anodal stimulation Double stimulation
Right side Left side
Case 2. A 18-year-old woman with left sided vestibular neuritis

Fig. 10. Galvanic Body-Sway responses in patients at 0.6 mA for 10 sec.

present.

2. the galvanic body-sway responses in cases with vestibular lesions.

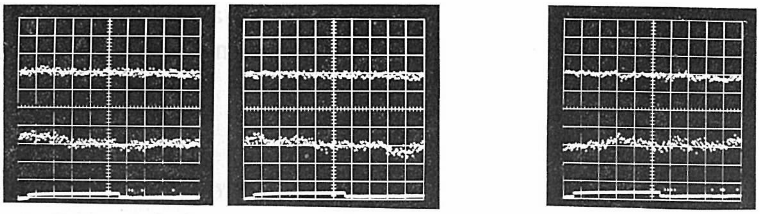
We come, now, to propose to review and analyse the galvanic body-sway responses in cases with vestibular lesions.

Case 1. This is a 35-year-old woman with left sided Meniere's disease, who developed hearing loss with tinnitus on the left side and attacks of vertigo since about five years. She has had disequilibrium. Examinations showed right-beating spontaneous and positional nystagmus in direction-fixed in type. Caloric tests showed no response on the left ear with normal on the right ear. Unipolar anodal stimulation showed normal galvanic body-sway responses on both sides. Double stimulation elicited no body-sway (Fig. 9).

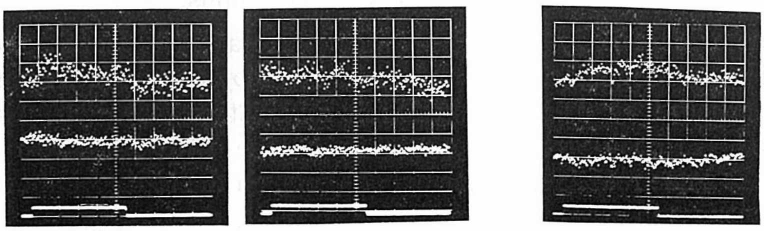
Case 2. A 18-year-old woman with left sided vestibular neuritis. Hearing tests revealed normal responses on both sides in audiometry. we found a right-beating spontaneous and direction-fixed positional nystagmus. Caloric tests showed no response on the left side with normal on the right side.

As shown in Fig. 10, unipolar anodal stimulation on the affected (left) side showed that the duration of the body-sway extended more than the normal data above mentioned at onset and cutoff of the stumlation, while the galvanic responses on the opposite (normal) side proved normal.

It seems to be important to note that anodal doulbe galvanic stimulation elicted body-sway to the opposite side (right side) in the lateral plane.



Unipolar anodal stimulation Double anodal stimulation
Right side Left side
Case 3. A 40-year-old woman with congenital Deaf-Mutism
Fig. 11. Galvanic Body-Sway responses in patients, 0.6 mA for 10 sec.



Unipolar anodal stimulation Double anodal stimulation
Right side Left side
Case 4. A 32-year-old man with left sided cerebellopontine angle tumour
Fig. 12. Galvanic Body-Sway responses in patients at 0.6 mA for 10 sec.

This body-sway, beyond any doubt, is due to the response of the none affected (right) side.

Case 3. This woman is a 40-year-old congenital deafmute. She showed off-balance with closed eyes on Mann's test and goniometer test. There was no spontaneous or positional nystagmus on examinations. No caloric response was present by ice water on both sides.

As shown in Fig. 11, unipolar anodal stimulation elicited on body-sway on both sides, and double stimulation elicited also no body-sway.

Case 4. This is a 32-year-old man with left sided cerebel 10-pontine angle tumour. Six months before examination he developed hearing loss on the left side and ataxia which were followed by facial parasis on the left side. Audiogram showed a 50 to 60 dB hearing loss characterized by a flat audiometric pattern in perceptive in nature on the left side with normal on the left side. On equilibrium tests his body fell towards the right side. There was a brisk right-beating directional-fixed positional uystagmus. Caloric stimulation on the left side by means of Dix and Hallpike technique elicited no nystagums with normal response on the right side (Fig. 12).

Unipolar anodal stimulation on the affected (left) side elicits no body-sway whereas on the right side galvauic body-sway response is normal. Anodal double stimulation elicits body-sway towards the epposite side. This phenomenon seems to be due to a response of the opposite side.

COMMENT

Although there is some point in dispute, it is generally agreed by many authors that galvanic current stimulats the endings of the vestibular nerve but does not act upon the vestibular sense organ proper in galvanic test. This opinion is based upon, beyond any boubt, results from the experimental works and clinical studies obtained by many investigaters. From this reason, otologists clinically utilize the galvanic test to differentiate between the labyrinthine diseases and vestibular nerve lesions.

In the present study we attempted to make a differentiation between lesions in the vestibular sense organ in the labyrinth and lesions in the vestibular nerve by using our galvanic stimulation technique. As above mentioned the body-sway responses in a case with Meniere's disease showed the same reactions to normal subjects, on the other hand the body-sway responses in cases with vestibular neuritis, deafmutism and cerebellopontine angle tumour showed an entirely defferent form from the normal subject's one.

From these results from the present study, it is possible to assert, beyond all guestion, that our galvanic stimulation technique is able to make clearly differentiation between labyrinthine lesions and vestibular nerve disturbances.

SUMMARY

The body-sway responses obtained by anodal unipolar and anodal double galvanic stimuɪation at 0.8 mA for 10 sec. were studied in 40 normal subjects and cases with vestibular lesions, such as Meniere's disease, vestibular neuritis, deafmutism and cerebellopontine angle tumour. The results obtained were processed and analyzed by a medical data processing computer.

The body-sway responses in normal subjects were divided into three groups. From the body-sway responses in patients it is possible to differentiate the labyrinthine lesions from the retrolabyrinthine disturbances by means of our galvanic stimulation technique.

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