Test for Galvanic Vestibular Responses

—Survey through our Experimental and Clinical Investigations for Last 20 Years—

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Galvanic vestibular responses, in wide sense, have been continuously studied in this Department of Otolaryngology, Yamaguchi University School of Medicine since 1955 from various standpoints of view.

The purpose of this paper are collectively to describe on, 1) brief historical review from the outstanding literatures on the various kind of galvanic test; 2) reviewing the results obtained in the experimental and clinical studies at the Department; 3) comment on Galvano-ARG of body-sway and its diagrammatic expression as Galvanogram (Sekitani), and its clinical use; and finally about 4) modern galvanic test with computer analysis of induced body-sway (called as computer Galvano-ARG).

LITERATURE REVIEW

Before the beginning of the nineteenth-century, Volta, who constructed the first battery producing a continuous electric current, applied a current to his head and experieuced a sensation of dizziness (Augustin, 1803).

Purkinje (1820) also showed that a galvanic current flowing through the head caused an upset in the equilibrium. Hitzig (1871) noted that an electric current sent through the head of a subject elicited eye movement (galvanic nystagmus). However, it was Breuer who first recognized the vestibular apparatus as the site of origin of this phenomenon.

Ewald experimented with pigeons and concluded that the galvanic current stimulates the fine endings of the vestibular nerve but does not act upon the vestibular sense organ proper.

Thenafter, many experiments and several hypotheses and theories of galvanic reaction were issued and supported by individual investigators.

These theories reveal that a definitive description of a galvanic reaction has not yet been found. It seems likely that the peripheral sense organ as well as the proximal nerve trunk or in the brain stem can be considered as the site of the galvanic reaction.

The galvanic reaction was introduced as a clinical test by Neumann (1907), Bárány (1907), Mackenzie (1917), Ruttin (1926), Brünings (1911), and others[3].

The galvanic test, as generally accepted, is used to differentiate disease of the labyrinth from affections of the vestibular nerve (retrolabyrinthine lesions). The test is therefore indicated in a case in which, for example, the labyrinthine excitability under caloric, mechanic, and turning stimulation is absent, so that it becomes important to know whether or not the galvanic reaction can be elicited. A positive response indicates a labyrinthine disease; a negative reaction points to the possibility of retrolabyinthine lesion. Even though many reports on galvanic reaction issued, there are some lacks in the fundamentals of the galvanic reaction.

Reviewing the literature, Northington, P. and Barrera, S.E. (1973) experimented the galvanic nystagmus reaction in the monkey.

They depicted that in the normal monkey a current of 1 to 3 mA produced a normal type, horizontal nystagmus with the electrodes in both ears. And, they also, explained that the direction of the nystagmus elicited (quick component) was always toward the cathode with the electrodes in the two ears.

Furthermore, they concluded that clinically the test would seem to be of value in distinguishing nerve degeneration in cases where the galvanic or rotation tests indicate peripheral vestibular dysfunction; i.e., a positive galvanic response in the presence of a negative caloric response on the side of vestibular dysfunction indicates that the eighth nerve is not degenerated on that side.

Fischer, J. (1956) described in his book, "The Labyrinth", that in human subjects, by bipolar test, a galvanic nystagmus toward the cathode occurs at 2 to 5 milliampers.

Despite these observations, no conclusive results as the change in the nystagmus with degree of voltage which one of the important influencing factor of electric stimulation.

Further experimental and clinical study on the influence factors such as: current intensity, voltage, and constant or pulse current, and etc. will be needed.

Reviewing the articles issued from the Department

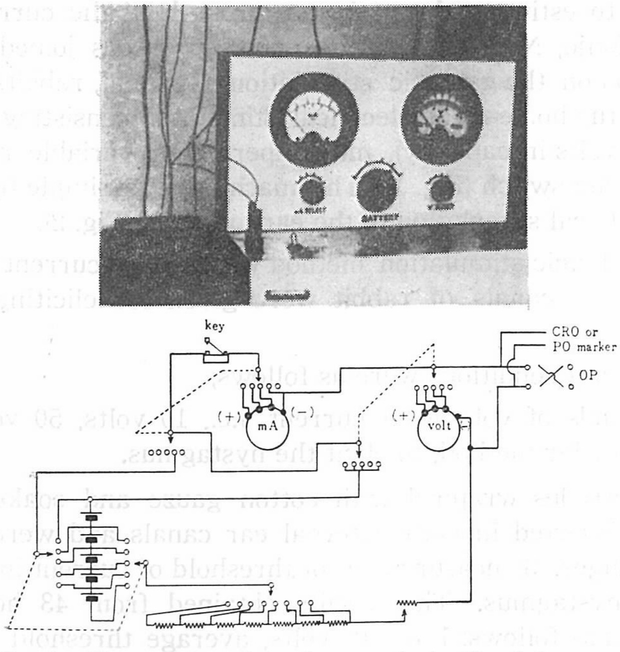
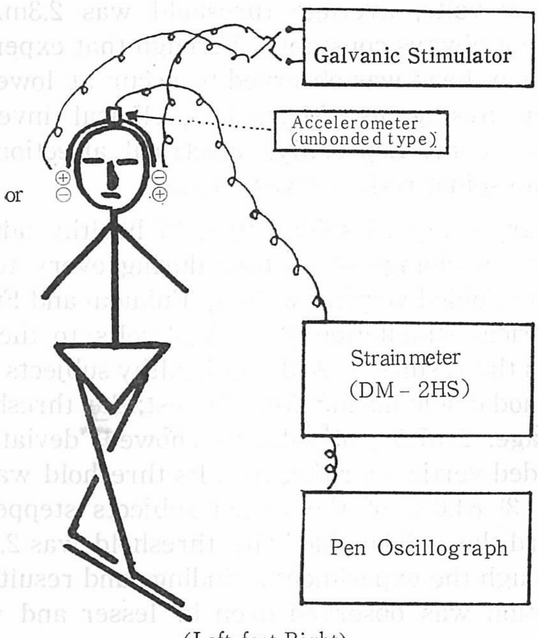


Fig. 1. Electrical Stimulator (home-made, by Nonaka)
mA: milliampermeter
Volt; voltmeter
OP; electrodes



Mann's posture (Left foot-Right / Right foot-Left) Eyes closed

Fig. 2. Block diagram for Galvanic test in Mann's posture.

In order to estimate the optimum strength of the current eliciting nystagmus, Honjo, Nonaka, Mashida and co-workers joined the project of investigation on the galvanic stimulation in animal, rabbits since 1955. They devised the home-made electrical stimulator consisting basically of batteries (100 volts in capacity), milliampermeter, variable resisters and polarity-changing switch (Fig. 1). The machine was simple but enough to apply the electrical stimulation to the ear-mastoids (Fig. 2).

Bipolar galvanic stimulation method with square current through the external acoustic canals of rabbit were given for eliciting nystagmus (Mashida, 1960).

Experimental conditions were as follows;

1) three kinds of voltage of current, i.e., 10 volts, 50 volts and 100 volts; and 2) bipolar method, to elicit the nystagmus.

Two electrodes wrapped with cotton gauze and soaked in saline solution were inserted in both external ear canals and were fixed with adhesive bandages. 3) measurement of threshold of current in milliamper, for eliciting nystagmus. The results obtained from 43 healthy adult rabbits showed as follows: 1) on 100 volts, average threshold for eliciting nystagmus was 3.48 mA. Most of the animals showed horizontal nystagmus toward the cathodal side, but a few of them did not show a constant directioning; 2) on 50 volts, average threshold for nystagmus was 2.3 mA. Horizontal nystagmus was elicited but the direction of it was not always constant; 3) on 10 volts, average threshold was 2.3mA. Direction of nystagmus was not always constant. Through that experiment, deviation of the eye and/or of head was observed to occur at lower intensity than that for eliciting nystagmus. Meanwhile, clinical investigation of the galvanic test was done. Especially, electrical affection on the routine tests for vestibulo-spinal reflexes was studied.

As preliminary study (Mashida, 1960), 27 healthy adults were examined for studying the change of posture during every tests, i.e., Mann's standing test, blindfolded vertical writing (Fukuda) and Fukuda's stepping test under electrical stimulation (0.4 mA., 4 volts) to the mastoid process on both sides. As the results, 1) 96.3% of healthy subjects examined leaned and fell to the anodal side during Mann's test; the threshold was 2.6 volt, 0.26 mA in average. 2) 87.5% of subjects showed "deviation to the anodal side" in blindfolded vertical writing test; Its threshold was 3.6 volts, 0.23 mA in average. 3) 84.0% of the tested subjects stepped side showing "deviating toward the anodal side"; Its threshold was 2.6 volts, 0.23 mA. in average. Through the experimental findings and results, these galvanic vestibular affection was observed even in lesser and weaker stimulus.

threshold that for eliciting nystagmus, without any noticeable complaint, such as pain or discomfort.

Following that introductory experiments, clinical use was started as galvanic test for the vestibulospinal reflexes. Patient with peripheral labyrinthine disorders were selected through the oto-neurological clinic of Yamaguchi University Hospital. Most of the patients (7 cases) who had "bilateral dead labyrinths" showed abnormal galvanic responses, revealing "no or less electrical affection" of their postures during Mann's test, Fukuda's writing test and stepping test (Fukuda). Conclusively, in his articles (Mashida, 1960) the galvanic affection on the vestibulospinal reflexes, in other words on the reflex tonus of the upper and lower extremities, was well observed quite qualitatively in accordance with some clinical figures.

Comment on Galvano-ARG of Body sway.

Sekitani (1965) reported the paper of his study, Galvanic test—Acceleration registrogram of Head movement induced by galvanic stimulation, and Galvanogram (Sekitani). The purpose of the investigation was to make a routine procedure of galvanic test as more qualitative and more quantitative estimation for human equilibrium as a link of vestibular function tests. First, the intensity of galvanic stimulation was settled in weak, but to be strong enough to induce a head movement and/or falling reaction when the subject stand in Mann's test posture. Three different intensities of current were finally settled. These were 0.25mA, 0.5mA and 1.0 mA. Bipolar and bi-retro-auricular stimulation method was the most convinient and comfortable in the subjects.

A 10 second stimulation of 0.25mA DC current does not usually cause any head sway or falling reaction in normal human adults; 0.5 mA stimulation makes the half of them to fall; 1.0 mA stimulation induced to fall quickly in most of all examinees. In the second point of this study, recording of head-body sway or falling movement was done by means of acceleration registrographic technique (Accelerometer on the top of helmet→strainmeter→oscillograph), called as Acceleration Registrograpby (abbreviat: ARG) As the 3rd point of interest in the study, the falling time induced were measured in every kinds of stimulation threshold on each side of stimulating electrodes placed. The data of falling time in 6 different stimulating condition were obtained from every examinees (Fig. 3). These values of different 6 falling times and patterns of ARG were plotted and expressed on the graphic scale, which is apparently similar to so-called calorigam, as called as Galvanogram (Sekitani) (Fig. 3 and 4) Average falling time induced by galvanic test in the group of healthy adults are 8.3

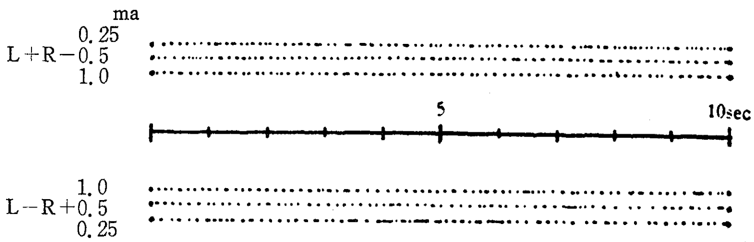


Fig. 3. Graphic scale sheet of Galvanogram (Sekitani).

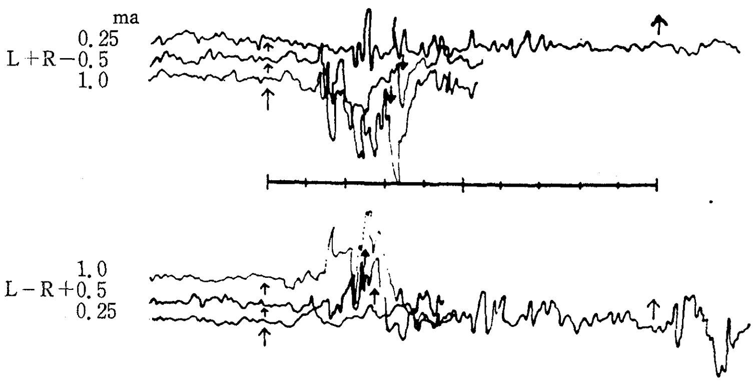


Fig. 4. Galvanogram of normal adult. (Type I: Normoexcitable)

sec. in 0.25 mA stimulation; 4.4 sec in 0.5 mA, and 1.9 sec by 1.0 mA stimulation. No significant difference on both sides was observed in laterality. No side effect or discomfort sensation during the test was observed.

Matsumoto (1970) reported that Clinical Studies on Galvanic Test-Body Sway on upright posture induced by Galvanic stimulation–.

He summarized the results from clinical cases who were examined with other routine otoneurological tests at Oto-neurological Clinic of University Hospital. And divided the cases upon classification of Galvanogram by Sekitani (1965).

And he explained the results being compared with other routine test that Galvanogram Type I was mostly comprised with the cases who have a normal vestibular response to alternate cold and warm caloric stimulation and normal righting reflex, including the cases diagnosed as motion sickness, Ménière disease, post-traumatic epilepsy, hypotensive dizziness, congenital nystagmus (so-called as normoexcitable). Galvanogram Type II (Fig. 5-1) was, to be as hyperexcitable, comprised with the cases who have

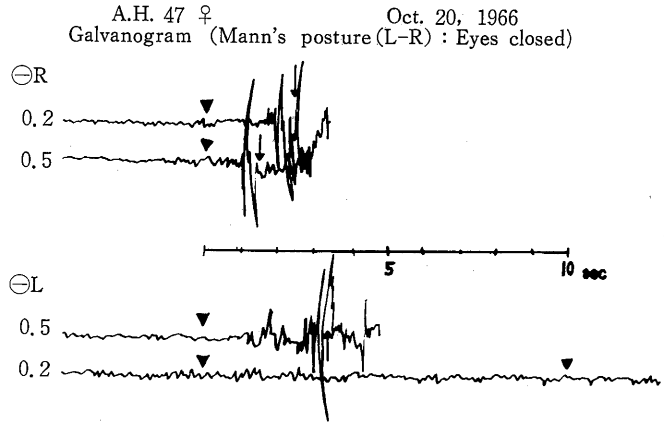


Fig. 5-1. Galvanogram of case with congenital deafmute.

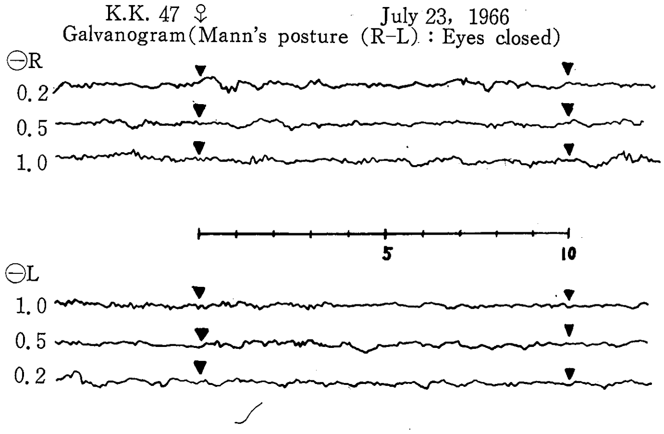


Fig. 5-2. Case with headtrauma.

Fig. 5. Galvanogram of cases.

a normal or relatively lowered vestibular responses and remarkably disturbed righting reflex, including the cases diagnosed as autonomic disturbance with hypotension, some of Ménière disease, serous labyrinthitis in post-tympanoplasty, sudden deafness and so. Galvanogram Type III (Fig. 5-2) was consisted of the cases who have the lowered vestibular response and slightly disturbed righting reflexes, being diagnosed as state in post-headtrauma and Ménière's disease. Galvanogram Type IV was comprised with deafmute and acquired deaf due to congenital syphilis with dead labyrinth.

These results mentioned above comfirmed the clinical availability and

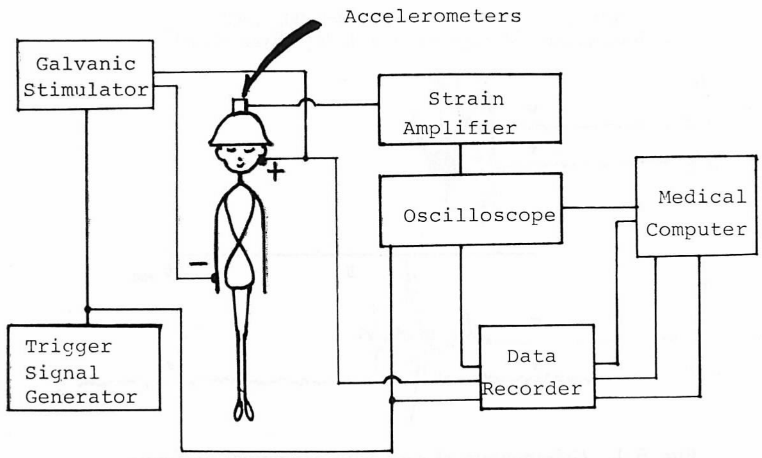


Fig. 6-1 Block Diagram for signal averaging Computer Galvano-ARG. Note the unipolar anodal stimulation method and the posture standing upright on feet side by side.

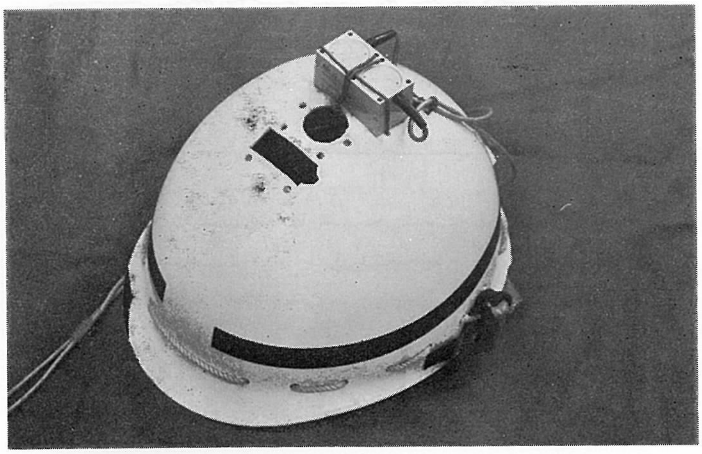


Fig. 6-2. Accelerometers on the top of helmet.

encouraged further investigation on the galvanic test.

Furthermore, Honjo (1970) used a high-speed cinephotographic recording and analysis on the body-sway during galvanic test, and commented on the results comparing the unipolar, bipolar and double electrodes test methods.

Modern Computer Analysis of Galvanic Body Sway (Computer Galvano-ARG)

In this way, the qualitative and quantitative method to record the body sway induced by weak galvanic stimulation has been developed with several new electronic equipments, i.e., electronic stimulators, current controller and the medical computer (Fig. 6-1, and 6-2)

As partly mentioned alread there was some difficulty in differentiating the recorded small wave in ARG traces between an ordinary body oscillation of human and the body-sway induced by these weak stimulation. To solve the problem, Tanaka applied the averaging technique using with a medical data processing computer to magnity the small incidence in traces of ARG and detect certain meaningful signal of body-sway respones.

Tanaka (1973) reported his article entitled: Investigation of Galvanic Test—Analysis of Galvanic Body-Sway using Medical Data Processing Computer. He obtained the mean value of the parameters in the new test from the normal human adults and collected the interesting clinical data on the cases with dizziness. Here, brief explanation on recent test procedure of Galvanic test (called as "computer analyzed Galvano-ARG") in this Department was made (Fig. 7).

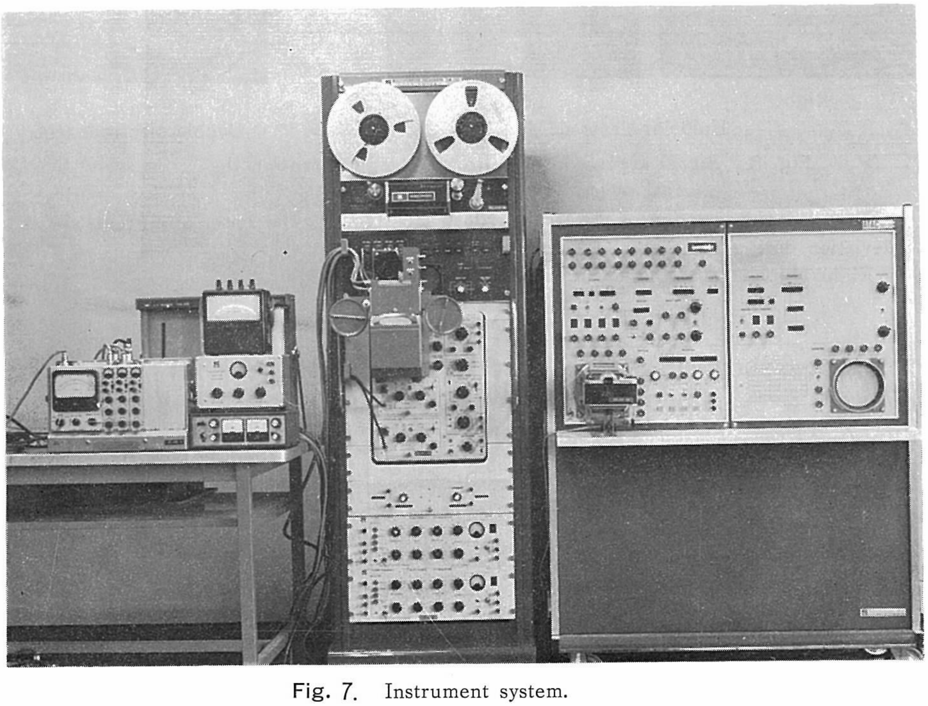
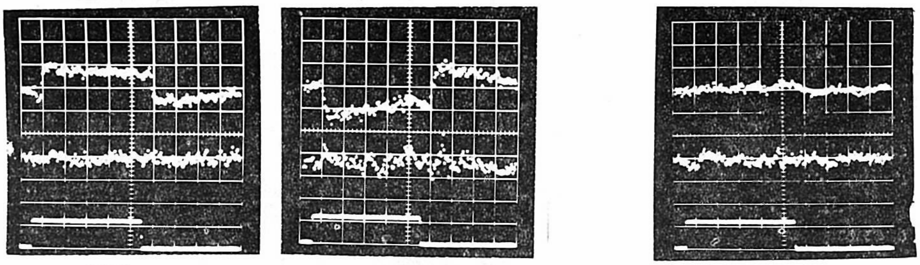


Fig. 7. Instrument system.
1. Electronic stimulators. 2. Strainmeter. 3. Oscilloscope.
4. data recorder. 5. medical data processingcomputer.

The test subject was asked to stand upright on both feet closed side by side, which his arms at his side, and then asked to close his eyes during test. Eight stimuli were repeatedly given to each retroauricular region in one test condition.

Stimulus current is settled as 0.6 mA DC of 10 sec. duration and repeatedly given in 15 sec. intervals through the unipolar anodal electrode or through the double anodal electrodes. Polarity of the current through each stimulating electrodes was always anodal in the present maneuver. Additionally, indifferent electrode was fixed at the contra-lateral forearm as same as ordinary electrode placement for ECG.

One sequence of the eight repeated stimulation and recording for test will take about 3 minutes.



Right Left
Unipolar electrode Double electrode test

Fig. 8. Signal averaged wave from the eight traces in the original record (from normal adult).

Note a rapid deviation of the trace upward (to right) at the onset of current, and deviation during the current flow.

Right unipolar anodal stimualtion --Rapid deviation to right.

Figure 8 showed the signal-averaged wave subsequently through the computer, averaging and superimposing the eight original traces of Galvano-ARG.

These signal-averaged waves showed definite trace of deviation to one side induced by weak galvanic stimulation though one original trace did not show.

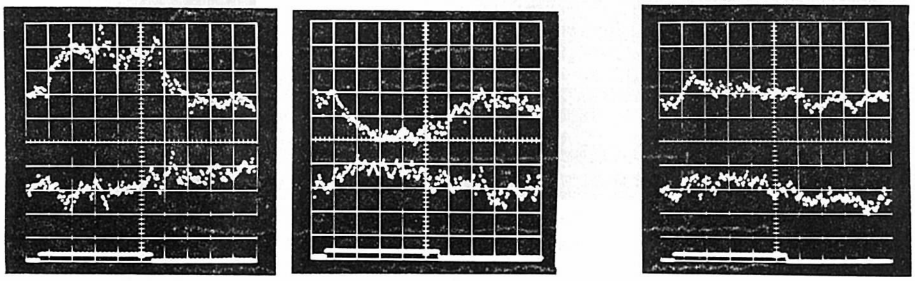
The fact to be emphasized in this test method are 1) no noticeable discomfort or pain in this level of stimulation current, 0.6mA; and 2) more comfortable posture (simple upright standing) for the examinee, than the previous test posture (Mann's test posture to produce some visible body-sway). And 3) unbelievable stability of the electrical current through the skin resistance, obtained by the current controller. Subsequently, reliable data of Galvano-ARG of the body-sway are possibly obtained.

Before closing this article, we should like to present the cases recently experienced in this oto-neurological clinic, briefly.

Figures of these results of computer Galvano-ARG will show definte change in regular response of the body due to affected lesion in the vestibular nerve system.

(Case 1) A 18 years old woman with left sided vestibular neuronitis was tested by the signal averaging computoer Galvano-ARG. In Fig. 9, unipolar anodal stimulation to the right side induced rapid deviation of the body to the right side, but the same stimulation to the left side did not elicit any definite or regular rapid response to deviate leftward though there was some sluggish response and somewhat slow deviation of the body to the left side at nearly 4 sec point on time course.

Galvanic Body-Sway Responses in Patients
at 0. 6 mA for 10 sec.



Unipolar anodal Stimulation — Right side — Left side; Double Anodal Stimulation

A 18-Year-Old Woman with Left sided vestibular neuroritis

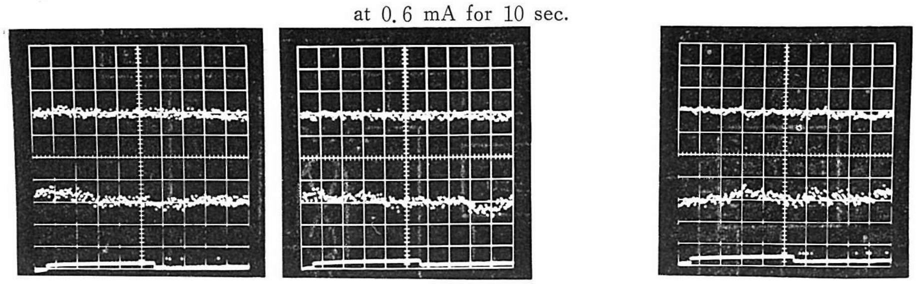
Fig. 9. Computer Galvano-ARG in the patient with left sided vestibular neuronitis.

At right side unipolar anodal stimulation, a fairly good rapid deviation of the ARG traces was observed, but relatively slow deviation at the left side stimulation. On double anodal stimulation, the ARG trace deviated to right, suggesting better responsible vestibular nerve [on the] right. In other word, the left vestibular nerve system had possibly lowered excitability or conduction impairment.

Furthermore, its sluggish rosponse of the body against the weak electrical stimulation was definitely demonstrated by double anodal stimulation showing "right-lateral deviation", suggesting delayed or very poor response in the left vestibular nerve system, in so-called "vestibulo-spinal reflexes, in general".

It is well in accordance with clinical feature and other otoneurological data.

Galvanic Body-Sway Responses in Patients
at 0. 6 mA for 10 sec.



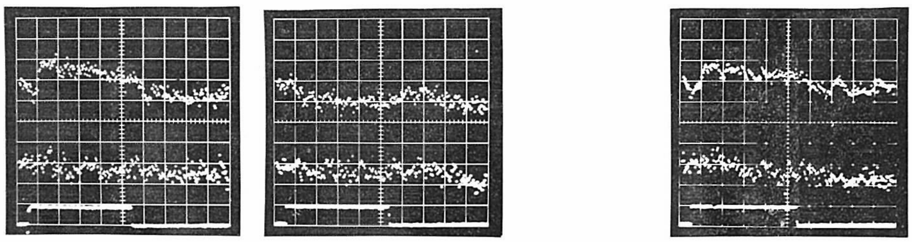
Unipolar Anodal Stimulation — Double Anodal Stimulation

Right side — Left side

A 40-Year-old Woman with Congenital Deaf-Mutism

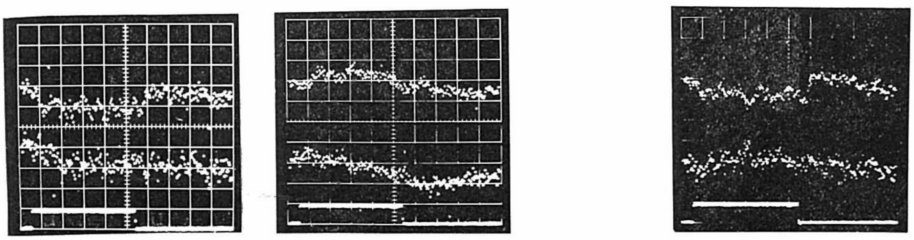
Fig. 10. Computer Galvano-ARG in patient with congenital deafmute, "dead labyrinths" proved by other tests.

Galvanic Body-Sway Responses in Patients
at 0. 6 mA for 10 sec.



Unipolar Anodal Stimulation — Double Anodal Stimulation

Right side — Left side



Unipolar Cathodal Stimulation — Double Cathodal Stimulation

Right side — Left side

A 57-Year-old man with Acoustic Tumor on the left side. The direction of the Body-Sway was changed with the polarity of the stimulating current. Body-sway was poorly induced with regular galvanic stimulation on the left side,in both anodal and cathodal. By the double electrode test, body-sway was observed, seemingly due to influence of the right healthy inner ear.

Fig. 11. Result from the case with acoustic tumor on the left side.

(Case 2) A 40 years old woman with congenital deafness with "dead labyrinth" detected by vestibular function test was studied by this computer Galvano-ARG, as shwon in Fig. 10, every waves of computer Galvano-ARG did not show any meaningful response in the body against the unipolar and bipolar anodal stimulation at all.

(Case 3) A 57 years old man with acoustic neuroma of the left side, which was clinically diagnosed by joint examination of oto-neurology and neurosurgical clinic and later was confirmed by surgery, was tested by the computer Galvano-ARG (Fig. 11).

Patterns of the waves of body-sway induced by anodal stimulation and also cathodal stimulation to the left mastoid showed no regular rapid response or deviation phenomenon of the body.

And by double anodal stimulation, there was abnormal deviation to the right side.

These results suggested that the left vestibular nerve system reduced its excitability and conduction capacity significantly.

CONCLUSION

Historical review of the literatures which are related to Galvanic test, especially for vestibulospinal reflexes was done. Reviewing of the articles related to galvanic test issued from the Department of Otolaryngology Yamaguchi University School of Medicine was briefly made, including some comment about galvanic test for body-sway induced by electrical stimulation, which recorded with acceleration registrographic technique (Galvano-ARG), and about assessment of the finding by Galvanogram (Sekitani).

Finally, the latest procedure of galvanic head-body sway test using with signal averaging computer technique, called as computer Galvano-ARG for Galvanic Body-sway Responses, was introduced showing the cases and its clinical significance for differential diagnoses.

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