Experimental Study on Galvanic Nystagmus

—Its Threshold and Direction of Nystagmus Induced in Rabbits—

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INTRODUCTION

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 experienced a sensation of dizziness (Augustin, 1803)[1].

Purkinje (1820)[2] also showed that a galvanic current flowing through the head caused an upset in the equilibrium. Hitzig (1871)[3] 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[4].

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 retrolabyrinthine lesion. Even though many reports on galvanic reaction issued, there are some lacks in the fundamentals of the galvanic reaction.

In this paper, auther presented the results of experimental study of electrically induced nystagmus in rabbits for the purpose of assessment of induced nystagmus and current intensities.

MATERIALS AND METHODS

Electric stimulator was designed consisting of 100 volts batteries, equipped with variable resistors, milliampermeter and polarity-changing switch. (Figure 1)

Electrodes of silver stick (0.5 cm in diameter) which was wrapped with cotton gauze and soaked in the saline solution were used. The electrodes were inserted in both external acoustic meatuses of rabbits and were fixed with adhesive bandages.

The forty-three healthy adult rabbits were used for this experiment; after selection tests consisting of otoscopic examination in the external ear canals, rotation test and alternate caloric test.

Electrical stimulation were applied by biaural-bipolar method, i. e., the anodal electrode was in the right external acoustic meatus, and the cathodal electrode in the left meatus.

Polarity was reversed by a polarity-changing switch, alternately by order.

Threshold for eliciting nystagmus, as the intensity of current was increased gradually, was measured by milliampermeter as accurate as possible; and the direction of nystagmus elicited was observed.

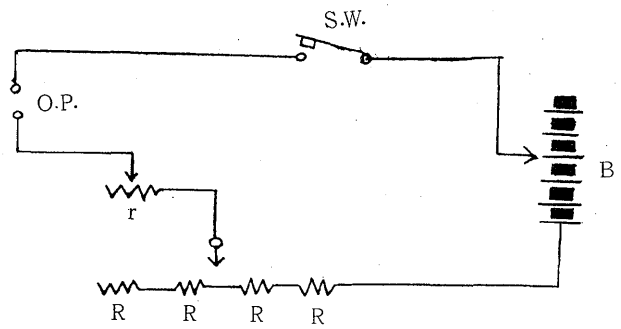

Fig. 1. Diagram of galvanic stimulator
S.W.: Switch (polarity changeable)
O. P.: Electrode
B.: Batteries

EXPERIMENTAL RESULTS

I. On 100 volts stimulation

a) Threshold of current intensity for nystagmus:

Constant electrical stimulation of 100 volts was sent through biaural-bipolar electrodes. Threshold of current intensity was measured by milliampermeter when nystagmus elicited by direct current produced by batteries and controlled by means of variable resistors.

i) The threshold for nystagmus elicited was 3.50 mA in average (Fig. 2) when the anodal electrode was in the left ear canal and the electrical current was "on".

ii) When the anodal electrode in the right ear canal and the current was "on", the threshold was 3.55 mA in average (Fig. 3).

b) Direction of nystagmus: The survey on the direction of nystagmus which was elicited by stimulation of 100 volts was made in the 11 rabbits showing definite direction during the experiments.

i) When the anodal electrode was on the left side and the cathodal electrode was on the right side, rightward nystagmus was observed in nine of the 11 rabbits and the remainder 2 of them showed leftward nystagmus as the current was on. And then, as the current flow was "off", 7 of them showed markedly to the rightward and two of them showed leftward nystagmus. The remainder 2 did not show any definite direction (Table 1).

ii) when the anodal electrode was on the right side and the cathodal

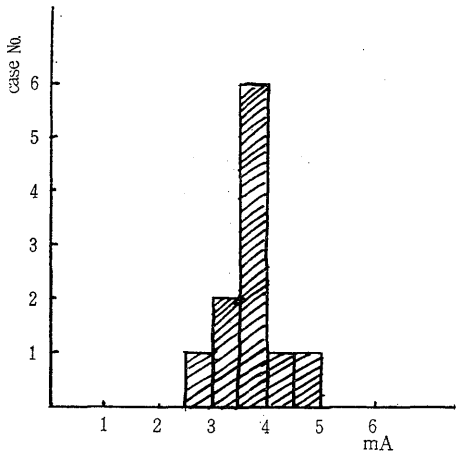

Fig. 2. 100 volts L⊕R⊖
Current: on

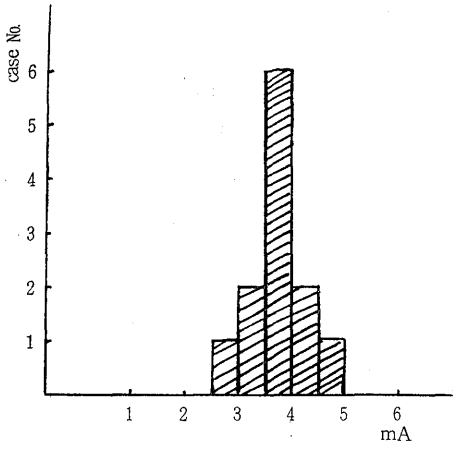

Fig. 3. 100 volts L⊖R⊕
Current: on

electrode was on the left side, six of the 12 cases showed leftward horizontal nystagmus and 6 was rightward horizontal nystagmus as the current was "off". And, as the current flow was "off", six cases showed toward left, four of them showed rightward horizontal nystagmus, and no definite nystagmus was in two cases (Table 2).

c) Brief summary: Threshold for nystagmus elicited by stimulation of 100 volts direct current was 3.5 mA in average. Direction of nystagmus was in most of cases toward the cathodal side.

Table. 1.

Direction of nystagmus elicited

100 Volts	R(+) L(−)	
Case No.	On Right←→Left	Off Right←→Left
102	←	←
109	←	←
96	←	←
100	←	←
103	←	→
92	←	←
91	→	←
93	←	(−)
71	←	(−)
60	←	→
70	→	←

Table. 2.

Direction of nystagmus elicited

100 Volts	R(−) L(+)	
Case No.	On Right←→Left	Off Right←→Left
102	→	→
109	→	→
107	→	←
96	←	(−)
100	→	→
103	←	→
92	←	←
91	←	→
93	←	←
71	←	→
60	→	←
70	→	—

II. On 50 volts stimulation

a) Threshold for nystagmus elicited by 50 volts stimulation was as follows(as shwon in Figs. 4 and 5): i) Threshold for nystagmus was 2.7 mA in average, when the anodal electrode was on the left side and the current was on.

ii) When the anodal electrode was on the right and the current was "on", threshold for eliciting nystagmus was 2.4 mA in average.

b) Direction of nystagmus elicited; i) when the anodal electrode was on the left side and the current was "on", the direction of nystagmus was rightward in eight of the 12 cases. And four of them showed leftward horizontal nystagmus. When the current flow was "off", the leftward nystagmus was seen in four cases and the rightward nystagmus was seen in 6 cases (Table 3).

ii) When the anodal electrode was on the right side and the current flow was "on", the leftward nystagmus was observed in four cases and the rightward nystagmus was in eight of them. Meanwhile, when the current flow was "off", the leftward nystagmus was seen in 4 cases and the rightward nystagmus was in 4 cases (Table 4).

c) Brief summary: By 50 volts stimulation under the bipolar method, the threshold was 2 mA in either polarity and even at "on" and "off", in average. This was relatively lower than that of value on 100 volts stimulation. Direction of nystagmus was in most of all cases toward the cathode side.

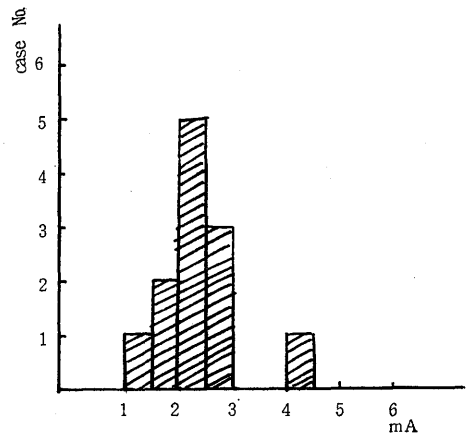

Fig. 4. 50 volts L⊕R⊖
Current: on

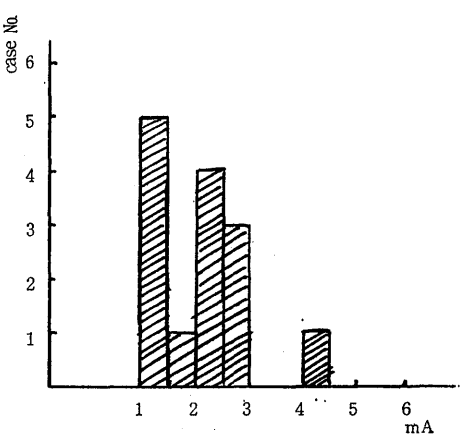

Fig. 5. 50 volts L⊖R⊕
Current: on

Table. 3.

Direction of nystagmus elicited

50 volts	R(−) L(+)	
Case No.	Right←→Left	Right←→Left
102	←	—
109	←	←
107	→	←
96	→	→
100	←	←
103	→	←
92	←	←
91	←	→
93	←	→
71	←	—
60	←	→
70	→	←

Table. 4.

Direction of nystagmus elicited

50 Volts	R(+) L(−)	
Case No.	Right←→Left	Right←→Left
102	←	→
109	→	—
107	←	←
96	←	←
100	→	→
103	←	→
92	←	—
91	←	—
93	→	←
71	←	—
60	→	←
70	←	→

III. On 10 volts stimulation

a) Threshold for nystagmus in each condition by 10 volts stimulation was as shown in Figs. 6 and 7.

i) When the anodal electrode was on the left side and the current was "on", threshold was 2.6 mA in average. ii) When the right anodal stimulation and the current was "on", threshold was 2.2 mA, in average.

b) Direction of nystagmus elicited by 10 volts stimulation was shown in Table 5.

i) When the anodal electrode was on the left ear canal and the current was "on", the direction of nystagmus elicited was rightward horizontal nystagmus in nine of 12 cases and the leftward was seen in three of the 12 cases. When the current was "off", the rightward nystagmus in four cases; and the remainder 5 cases did not show any definite direction of nystagmus.

ii) When the anodal electrode was on the right ear canal and the current was "on", the leftward horizontal nystagmus was seen in seven of the 12 cases.

The remainder 5 cases showed rightward nystagmus. When the current flow was "off", the leftward horizontal nystagmus was in 4 of the 12 cases. The rightward nystagmus was in 4. The remainder 4 cases had no definitely directed nystagmus (Table 6).

c) Brief summary: On 10 volts stimulation, the threshold for induced nystagmus was 2.4 mA in average in any conditions of stimulating electrodes. Direction of nystagmus was rather constantly toward the cathodal side. But, it was not constant as the current was "off".

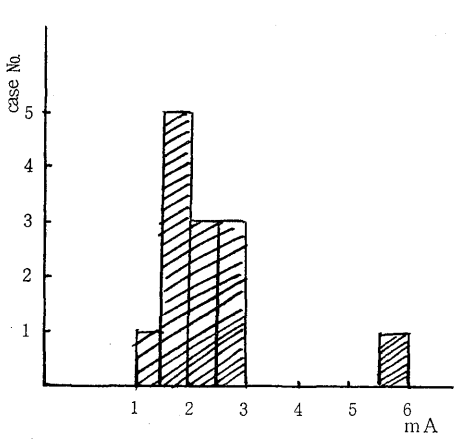

Fig. 6. 10 volts L⊕R⊖
Current: on

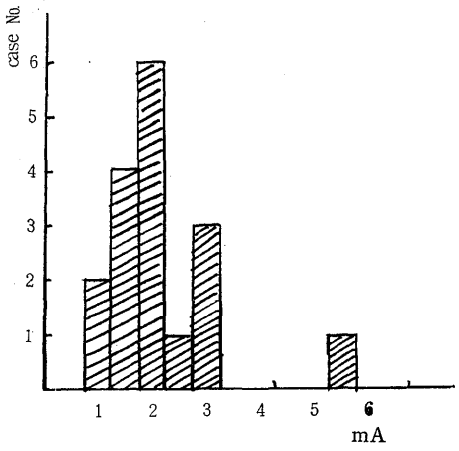

Fig. 7. 10 volts L⊖R⊕
Current: on

Table. 5.

Direction of nystagmus elicited

10 Volts	R(−) L(+)	
Case No.	On Right←→Left	Off Right←→Left
102	→	←
109	←	→
107	←	(−)
96	←	(−)
100	←	→
103	←	←
92	←	←
91	←	(−)
93	←	→
71	←	(−)
60	→	←
70	→	(−)

Table. 6.

Direction of nystagmus elicited

10 Volts	R(+) L(−)	
Case No.	On Right←→Left	Off Right←→Left
102	←	→
109	→	→
107	←	(−)
96	→	(−)
100	→	(−)
103	←	→
92	←	(−)
91	←	→
93	→	←
71	→	←
60	→	←
70	→	←

CONCLUSION AND COMMENT

Bipolar galvanic stimulations with direct square currents through the external acoustic canals were given for eliciting nystagmus in the experimental animal, rabbits. Experimental condition were consisted of: 1) three kinds of voltage of current, i.e., 100 volts, 50 volts, and 10 volts; 2) bipolar method with electrodes i.e., the anodal electrode in the left ear

canal and the cathodal electrode in the opposite right ear canal, and vice versa; 3) calculation of threshold of current, for nystagmus elicited was done at the closing of the circuit (on) and at the opening of the circuit (off).

The following results were obtained on each experimental condition: (Table 7)

Table. 7.

Threshold for nystagmus

Current & Electrodes	On	
	L(+) R(−)	L(−) R(+)
100 volts	3.50mA	3.55mA
50 volts	2.70mA	2.40mA
10 volts	2.60mA	2.20mA

1. On 100 volts stimulation, threshold for electric induced nystagmus, was 3.48 mA in average. Most of the animals showed horizontal nystagmus toward the cathode, but a few of them did not show any constant direction.

2. On 50 volts stimulation, threshold for nystagmus was 2.3 mA in average. Direction was not always constant. Horizontal nystagmus was elicited.

3. On 10 volts stimulation, threshold was 2.3 mA showing horizontal nystagmus. Direction of nystagmus was almost constant toward the cathodal side when the current circuit was closed. However, as the circuit was opened, direction of nystagmus was not always constant.

Above all, the threshold for nystagmus was lowered slightly by lowering the electric voltage.

Reviewing the literature, Northington, P. and Barrera S. E. (1937) 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 nystamus toward the cathode occurs at 2 to 5 milliampers.

Despite these observations, no conclusion 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, skin resistance, and constant square or pulse current and so on might be suggested earnestly.

Through the present experiment, we noticed also that some deviation of the eye or head-neck occurs usually at lower intensity of current than the current intensity be needed for evoking nystagmus itself.

SUMMARY

Galvanic nystagmus in the rabbits was observed eliciting by electrical stimulation through biaural-bipolar electrodes in the external acoustic canals. The threshold of nystagmus was calculated and its direction of nystagmus was observed. The results were as follows:

1. Threshold for eliciting nystagmus by 100 volts stimulation was 3.48 mA in average on both polarity.
2. Threshold by 50 volts stimulation was 2.4 mA in average.
3. Threshold by 10 volts stimulation was 2.3 mA in average.
4. Direction of nystagmus elicited was toward the cathodal side, however not always.

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