Studies on Square Drawing Test for Ataxia

I. Bimanual Method: Its Procedure and Results in Healthy Adults.

Keiko KANESADA, M. D.
Department of Otolaryngology Yamaguchi University School of Medicine
Ube, Japan

Square Drawing Test for ataxic disorder is designed by Sekitani, et al (1975) modifying after Fukuda's vertical writing test for evaluating the vestibulospinal reflexes.

Sekitani, et al (1975, a. b.) reported introductorily on the results of Square Drawing Test done by normal subjects and also done by patients with dizziness. In their paper, they stressed that the test is aiming more qualitative and quantitative analysis for ataxic disorder and more simplicity with universality.

So-called "writing test" in various way in neurology and oto-neurology are fairly described in the textbook, though little description in modern european and american publication of otolaryngology is available.

Meanwhile, several authors emphasized the necessity of performance by each hand on writing test after comparing the clinical results in cases with acoustic neuromas (Uemura) and in cases with cerebellar tumor (Sayk). And they introduced the way for writing test using with some simple letters or numerical letter.

The present author recognized also the necessity of bimanual performance on Square Drawing Test and made the Bimanual method of Square Drawing Test.

The purpose of this paper are to describe the procedures for test by each hand and quantitative analysis of the results obtained from the healthy subjects and from the patient in oto-neurological clinic to evaluate the clinical significance of this test.

METHOD AND MATERIAL

A special test paper for this bimanual method of Square Drawing Test (abbreviated to SDT (bimanual)*) was made as shown in Figure 1.

The subject was asked to draw a line with a soft feltpoint pen (fibrous pen; MAGIC PENTEL, TM in Japan) on and along the line of the thin printed squares, 40×40 mm in size, on the test paper. He was also asked to

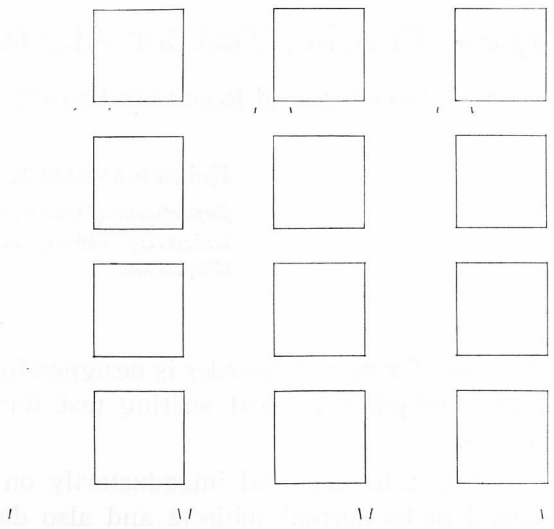


Fig. 1. Test paper for Square Drawing Test (Standard sheet) These squares are printed on the paper as a thin line. Length of the square are equal as 40×40mm. Each point on the test paper shows 10°degree angle point.

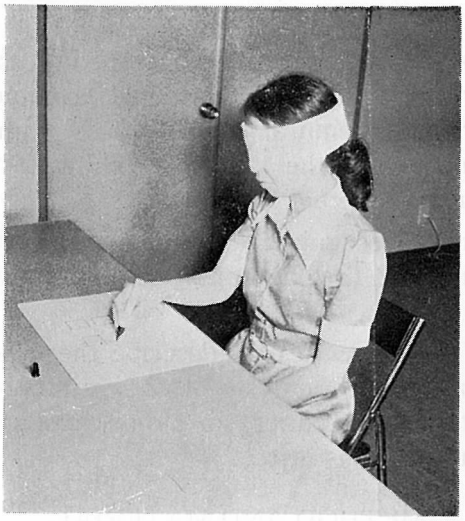
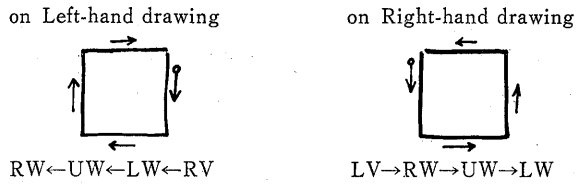


Fig. 2. Drawing the square line of four squares arranged vertically, with the open eyes first; and then the next four squares with the eyes covered. The subject is always asked to not touch any part of the arm and hand on the table or paper. And another hand on the knee.

not touch any part of the hand and arm on the table or paper at all during the test performance. The next instruction is to draw continuously the square line of four squares arranged vertically, with the open eyes, first. And then the next four squares will be drawn with the eyes covered and closed (Fig. 2).



RV : Right vertical down
LW : Leftward horizontal
UW : Upward
RW : Rightward

LV : Left vertical down
RW : Rightward horizontal
UW : Upward
LW : Leftward

Fig. 3. Order to draw the square by each hand.
The drawing will start from the left upper corner in occasion of riht hand drawing. In left hand drawing, start from the right upper corner, as shown in schema.

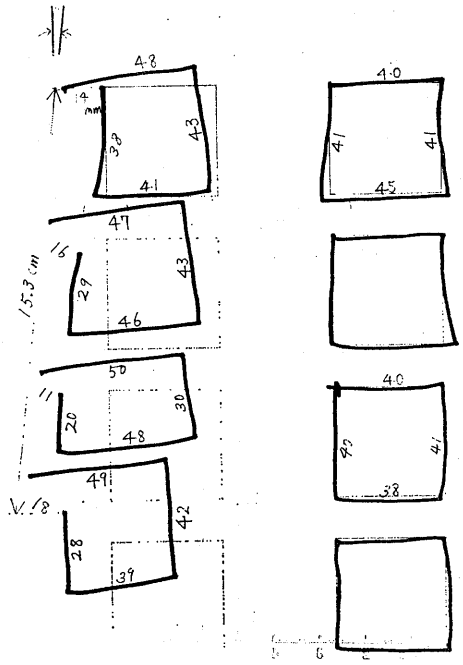


Fig. 4. Actual measurement of each length and angle of the drawn squares.

Since the drawing will start from the left upper corner (named as "starting point"), in occasion of right-hand drawing, of the pre-printed square, subsequently the drawing go vertically downward, then continuously to rightward horizontal, upward vertical and left ward horizontal to the previous starting point (named as "end point") (Fig. 3).

In occasion of left-hand drawing, the starting point is at the right upper corner, proceeding the drawing downward vertical, leftward horizontal, upward vertical and then rightward horizontal to the end point

There will necessarily exist a separation between the starting point and the end point (named as Distance S-E).

The following parameters in this test are obtained and calculated for comparison (Fig. 4).

1) Every length of lines of the drawn squares with the eyes covered are measured. (In some special case, the drawn squares with the open eyes will be measured, too)
2) Distance between the starting point and end point of each square (Distance S-E); comparing among every squares.
3) Distance between the starting point of no. 1 square and the starting point of no. 4 square (Distance 1-4)
4) Deviation angle of the squares to the vertical line. And then,
5) Describe the existence of derangement of the drawn lines.

Each value of the parameters measured are plotted on a scale for diagrammatic presentation of the results (Fig. 5).

The study comprised 30 healthy adult volunteers* who have no history of disease in acoustic-vestibular system.

They are 25 years old in average, ranging from 20 to 33 years of age and most of them are medical student. They did not have any practice of

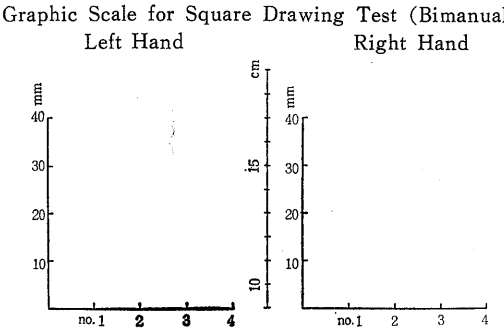


Fig. 5. Graphic scale for Square Drawing Test (Bimanual).

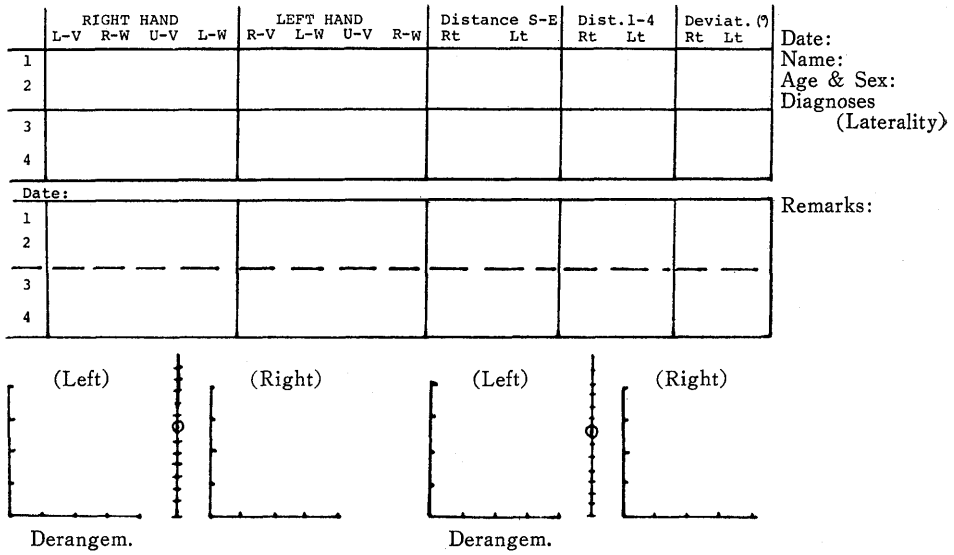


Fig. 6-1.

	Right hand				Left hand				Distance S-E		Dist. 1-4		Deviat.	
	L-V	R-W	U-V	L-W	R-V	L-W	U-V	R-W	Rt	Lt	Rt	Lt	Rt	Lt
1	37	36	39	41	40	38	46	48	9	13	146	162	3.5°	4.0°
2	33	36	35	44	38	38	34	50	13	14				
3	24	37	32	43	36	43	40	46	13	16				
4	35	38	43	40	34	43	40	42	12	9				

Date:
Name:
Age & Sex:
Diagnoses
(Laterality)

1	
2	
3	
4	

Remarks:

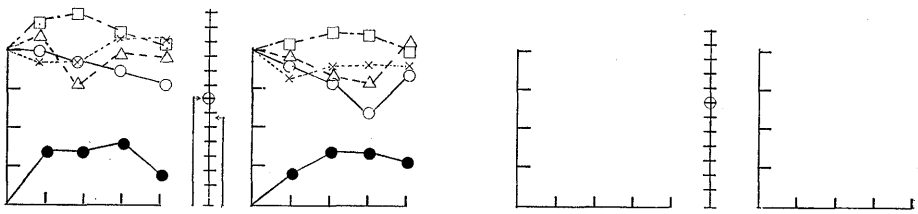


Fig. 6-2.

Fig. 6. Data sheet.

this kind of writing test before the study.

Meanwhile, the case study comprised 143 patient who consulted to this Otoneurological clinic (laboratory) with a positive symptoms of vertigo and ataxic disorder and/or without any symptom but with otitis media chronica as a check case before ear surgery.

Therefore, two companion paper are being prepared. One presents the general view and a statistical treatment of the result obtained from healthy volunteers.

The other, a similar study, shows the results from findings in the cases of peripheral or central lesions affecting balance and also in the cases from the otology clinic.

RESULTS

According to the procedure of this bimanual Square Drawing Test mentioned before, the following results are obtained from 30 healthy adults. For graphic representation, two figures of Square Drawing Test drawn by each hand are arranged in one sheet to show the results easily and clearly (Fig. 7).

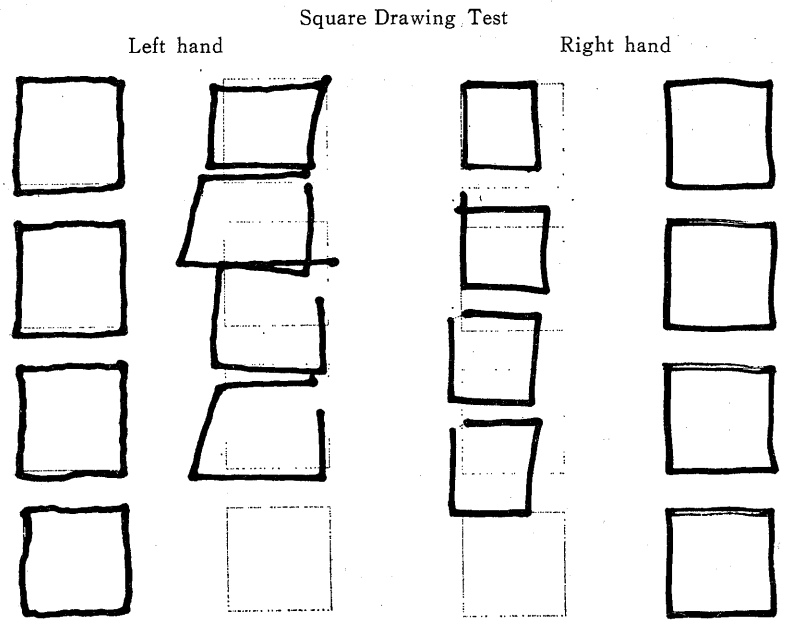


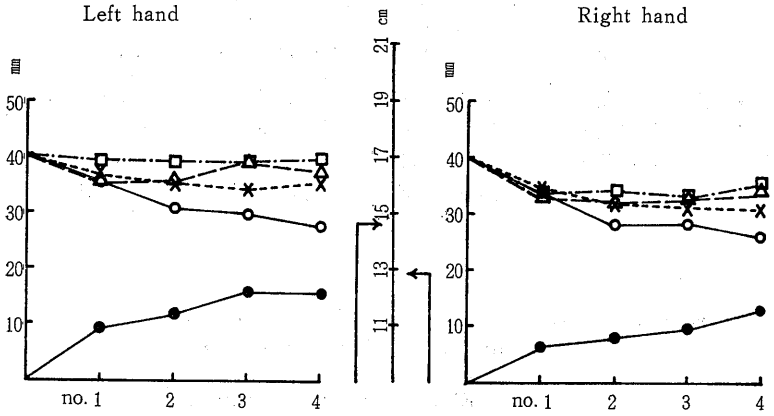
Fig. 7. An example of SDT drawn by a healthy adult.
Two figures drawn by each hand are arranged in one figure to show and to compare the results of the bimanual method of Square Drawing Test.

Mean value with standard deviation of every parameters are calculated from the original data and shown on Table I and II, and Fig. 8. Here, the findings of each parameter will be mentioned as follows;

1) Length of every line of the drawn squares.

There are some general tendencies; i) to draw the lines shorter when the eyes covered than that of the opened eyes (original length on test paper is 40mm) on each hand. It is somewhat greater in right hand drawing; ii) to draw the downward vertical line shorter than that of upward vertical; iii) to draw the last line of each square longer than the others ('elongation of the upper horizontal line', i. e., leftward horizontal in right hand drawing and rightward horizontal in left hand drawing); iv) to draw the lines of each square drawn by left hand relatively longer than that of right hand drawing; v) to become relatively shorter at the downward length (L-V in right hand drawing, R-V in left hand drawing) one square after another, from no. 1 to no. 4 square; vi) meanwhile, to be none or little difference in length of upper horizontal line (L-W in right hand, R-W in left hand drawing)

Graphic score of Square Drawing Test
Mean value of each parameters in 30 normal subjects.



(Legends of Figure and Table)

Fig. 8. Graphic Score of Square Drawing Test.
Mean Value of each Parameter of 30 Healthy Adults.

General Note:

	Right hand	Left hand
○——○	L-V	R-V
×·····×	R-W	L-W
△---△	U-W	U-W
□---□	L-W	R-W

●——● Distance S-E (Change in distance from the start to the end point)

Table. 1. Mean Value of Each Parameter in 30 Healthy Adults

	Right hand				Left hand				Distance S-E		Dist. 1-4		Deviat.	
	L-V	R-W	U-V	L-W	R-V	L-W	U-V	R-W	Rt	Lt	Rt	Lt	Rt	Lt
1	33.7	33.8	33.2	33.2	35.1	37.1	36.6	38.5	6.5	9.8	128.6	145.1	5.6°	4.6°
2	27.9	32.1	31.8	33.6	30.3	35.2	35.7	38.3	8.2	12.1				
3	27.8	31.4	33.4	34.3	29.2	34.4	38.5	38.2	9.7	15.7				
4	25.6	30.7	34.5	34.9	27.2	35.0	36.8	39.0	13.0	15.2				

(See the note of Fig. 3 and Fig. 8 for abbreviation)

Table 2. Length of the Lines of Square Drawing Test by Right Hand
—Mean Value and S. d. of Length—

	No. 1 Square	No. 2 Square	No. 3 Square	No. 4 Square
L-V	33.7±5.16	27.9±5.46	27.8±6.35	25.6±5.01
R-W	38.8±5.78	32.1±5.18	31.4±5.75	30.7±6.13
U-W	33.2±4.71	31.8±6.12	33.4±7.73	34.5±7.49
L-W	33.2±6.38	33.6±6.64	34.3±5.76	38.9±7.01

Length qf the Lines of Square Drawing Test by Left Hand
—Mean Value and S. d. of Length—

	No. 1 Square	No. 2 Square	No. 3 Square	No. 4 Square
R-V	35.1±5.36	30.3±6.20	29.2±5.52	27.2± 4.94
L-W	37.1±5.23	35.2±5.89	34.4±6.54	35.0± 7.14
U-W	36.6±5.79	35.7±7.83	38.5±7.04	36.8± 6.39
R-W	38.5±7.94	38.3±6.96	38.2±7.43	09.0±10.03

Table. 3. Square Drawing Test (Bimanual Method)
—Mean Value with S. d. of Distance S-E—

	Right Hand	Left Hand
No. 1	6.5±4.5	9.8±5.0
No. 2	8.2±5.3	12.1±6.6
No. 2	9.7±5.9	15.7±8.5
No. 4	13.0±6.8	15.2±8.3

Table. 4. Square Drawing Test (Bimanual Method)
—Mean value with S. d. of Distance 1-4—

Right Hand	128.6mm±21.75
Left Hand	145.1mm±19.48

Table. 5. Deviation in the Square Drawing Test (Bimanual Method)

Deviation	Right Hand	Left Hand
Angle (absolute)	5.6° (30 case)	4.6° (30 case)
Rightward	6.5° (22 case)	4.5° (13 case)
Leftward	3.6° (7 case)	5.3° (15 case)
No Deviation	0.0° (1 case)	0.0° (2 , ase)

2) Distance between the starting point and the end point (Distance S-E).

Mean value with standard deviation are shown in Table I and III, and Fig. 8.

In general, Distance S-E, in other words "separation", are larger in left hand drawing than that of right hand drawing.

Distance S-E at each square from no. 1 to no. 4 become larger gradually, but not steeply increase, and fairly restricted within nearly 15 mm in right hand drawing.

3) Distance between the start point of no. 1 square and that of no. 4 (Distance 1-4).

Mean value with standard deviation are shown in Table I and IV, and Fig. 8. Distance 1-4 on right hand drawing is 128.6 mm in average, and 145.6 mm on left hand drawing.

In Fig. 8, these results are recorded at the side of median pillar scale by cm.in length. Otherwise, Distance 1-4 on this test paper is 16.5 cm when drawn with the opened eyes.

4) Angle of deviation during Square Drawing Test.

Mean value are shown on Table I and V.

Deviation angle in absolute number are 5.6° (degree) on right hand and 4.6° on left hand drawing, in general.

Deviation angle are 5.6° on right hand drawing, consisting of 6.5° to right ward in average of 22 subjects in total 30 adults, and of 3.6° to left ward in average of 7 in 30 persons; One shows no measurable deviation

during drawing even with the eyes closed and covered. Otherwise, deviation on left hand drawing are shown as smaller, including no notable deviation in two persons. Generally, these 30 healthy adults showed slight tendency to draw the vertical lines deviating to right than to left.

5) Derangement of the line drawn with opened eyes and with the eyes covered.

Derangement, irregular vibratory and tremorous drawing, was not observed in the Square Drawing Test done by 30 healthy adults, drawn by right hand. A weak derangement-like figure is observed on the lines drawn by left hand of the right-handed person. In some person, the figure of lines drawn with opened eyes seems to be derangement already, but there is no tendency to increase the degree of derangement even when the eyes covered and closed. It does not increase anymore during the drawing one square after another.

COMMENTS

It is oftenly stressed that studies of the vestibulospinal reflexes have been contributed to a better understanding of the vestibular system in wide sense.

However, there is seemingly some tendency to pay little attention and to describe relatively less about clinical test for vestibulospinal also deiterospinal reflexes in the up-to-date Textbook of Otolaryngology and even in the literature appeared in medical journals in the world, except for Japanese literature. Most of the vestibular laboratory pay much about nystagmus and eye movements.

Though Wodak (1957) emphasized its necessity as "in every vestibular examination attention should be drawn not only to nystagmus but also to the deiterospinal reflexes", there is scattered description about the test for vestibulospinal reflexes which especially manifest on the upper extremities; but limited usually the past pointing test.

Reviewing the literature on the test for vestibulospinal reflexes by upper extremities, there are the famous reports, i. e., the past-pointing test of Barany (1910), the arm deviation test by Barany (1911), Güttich (1914) and Wodak & Fischer (1922).

Fischer & Wodak (1924) showed a direct graphic recording of the deviation of the movements of the arms, simply by letting the patient hold a pencil in each hand press against a downward moving sheet of paper. This idea developed to Talpis's photographic method (1927), eliminating the tactile influenece by mounting electric lamps on the fingers and could

thus record their movements.

This method was refined by Nyman (1945) in his big article, studying on both tipping and pointing by means of photographic recording in normals and in patients.

The fact that lateralization observed on the past pointing test will occur on the side of the slow phase of nystagmus induced is well known.

Fukuda (1957) explained that similar situation (finding) had been proved in his blindfolded vertical writing test, of which he devised the test method and reported in Japanese early 1940 and in 1957 in English. To be emphasized through his extensive study, the blindfolded vertical writing showed marked deviation and thus demonstrated functioning of the labyrinthine reflexes. He commented that the deviation in writing test, induced by such mild labyrinthine stimulation, i. e., a slow rotation (2 turns /10 sec) or caloric test would suggest to be probably due to a quite different mechanism of manifestation of nystagmus and of writing deviation between both reflexes vestibulo-ocular reflexes and vestibulo-spinal reflexes.

Meanwhile Unterberger found and explained in his paper entitled "Der Tretversuch" that most of right-handed persons rotated slightly to the left and moved a little forward. And left-handed persons often rotated slightly to the right.

On the literature, Uemura, et al (1963) stressed the necessity to do blindfolded vertical writing test by each hand. They reported clinical studies on acoustic neuroma, describing that 1) the result of caloric test was abnormal in 100% of cases; 2) the abnormal results of the past pointing test, stepping test (Fukuda), Romberg test and blindfolded vertical writing test (Fukuda) were obtained in significantly high ratio; in addition, they stressed with very important meaning the blindfolded vertical writing test done by only right-hand showed the different results depending on the side of the tumor, namely 58% in the case with the left tumor and 89% in the right side.

These results will suggest a need to compare the findings of writing test written by each hand independently.

Sayk (1963) proposed the writing test by each hand using with numeral letter 3, detecting abnomality in cases with cerebellar tumor.

Here, the deepest want to have a routine oto-neurological test for detecting a disturbance in the vestibulospinal reflexes or for ataxic disorder arose. Such a test will be done more easily by each hand and recorded in chart at the same time; and also more quantitatively in

assessment and will be able to do by every one who have different writing habit and who are in different intellectual level. Thenafter, the Square Drawing Test was offered to use in clinic.

This new Bimanual Method of Square Drawing Test was applied to 30 healthy adults for obtaining the results for settle some normal range in each parameter.

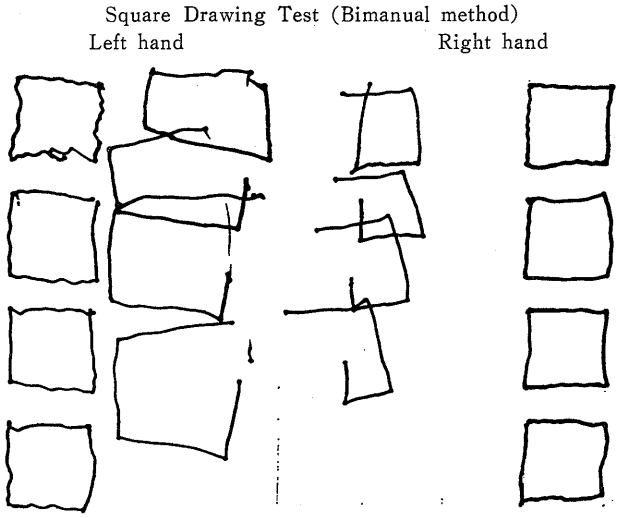


Fig. 9. Abnormal figure of Square Drawing Test (Bimanual method). (Case 1)

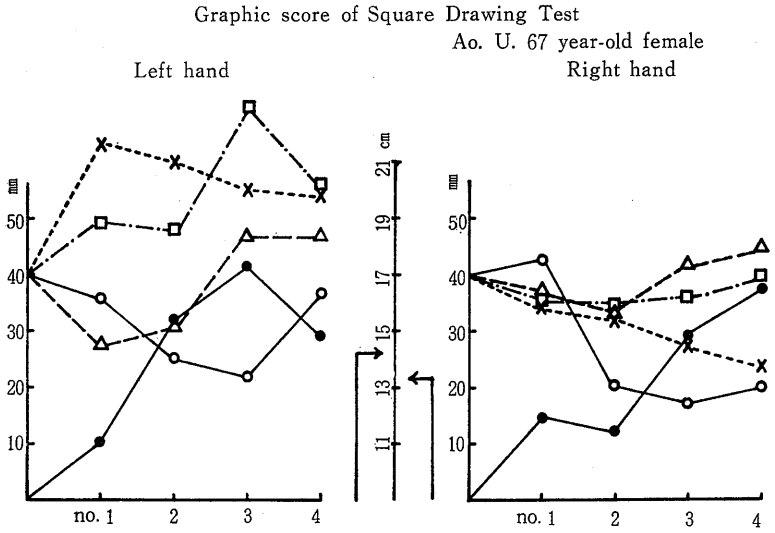


Fig. 10. Graphic score of SDT (Case 1)

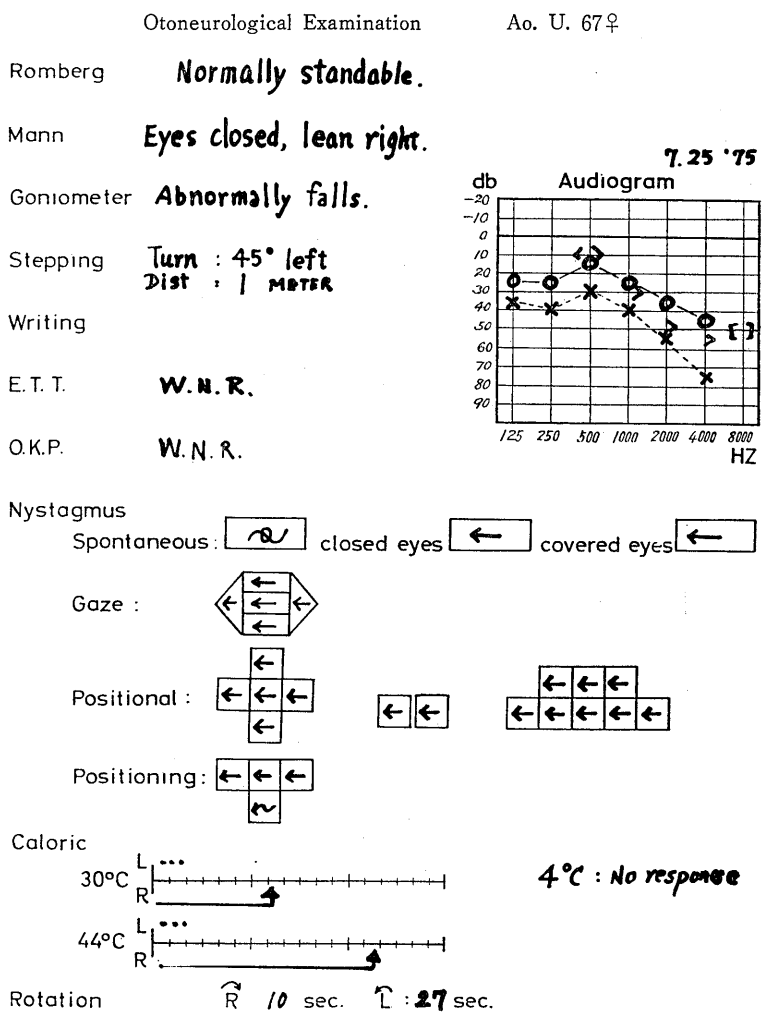


Fig. 11. Data of oto-neurological examination. [Case 1]

Five parameters are settled in this simple test and are nominated as already mentioned. Mean value and standard deviation are calculated and tabulated on every Tables. It however seems that further control studies will have to advance on more large number of control subjects ranging from the youngster to the aged in various age and sex distribution, and, if possible, in various group of man with different writing habit. To collect this kind of data of the test is seemingly important as same as to collect various pathological samples of data from the clinical cases.

Additionally, a brief case report was made to understand how the five

parameters in this test will be considered and how this test will be advanced in the next.

[Case 1] A 67 years old female patient with severe herpetic lesion over the left half of the face and ear, accompanied otalgia and dizziness. Thenafter, facial palsy developed.

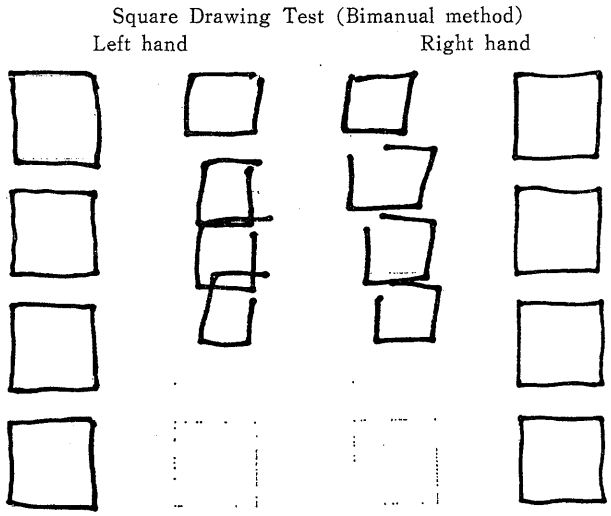


Fig. 12. 'Micrographic' figure of SDT.

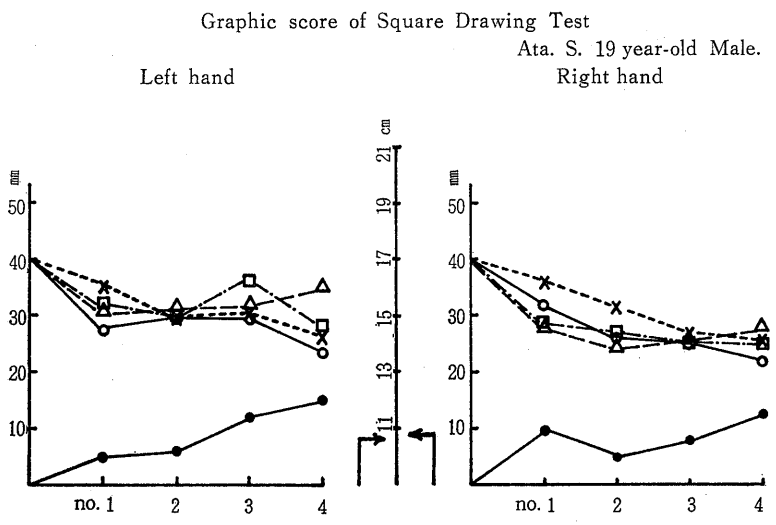


Fig. 13. Graphic score of SDT. (Case 2)
'Micrographic' but symmetrical figures remained are well demonstrated on SDT graph.

As shown in Fig. 9, Square Drawing Test showed abnormal findings in each parameter, which representing graphically in Fig. 10. Oto-neurological data in routine was described in Fig. 11.

[Case 2] A 19 years old male patient with chronic headache and progressive blurring vision (to double vision), manifesting spontaneous nystagmus. Diagnosed as sphenoid sinus tumor and intracranial invasion to the basilar space.

Bruns nystagmus was considered and paralysis of the left abducens

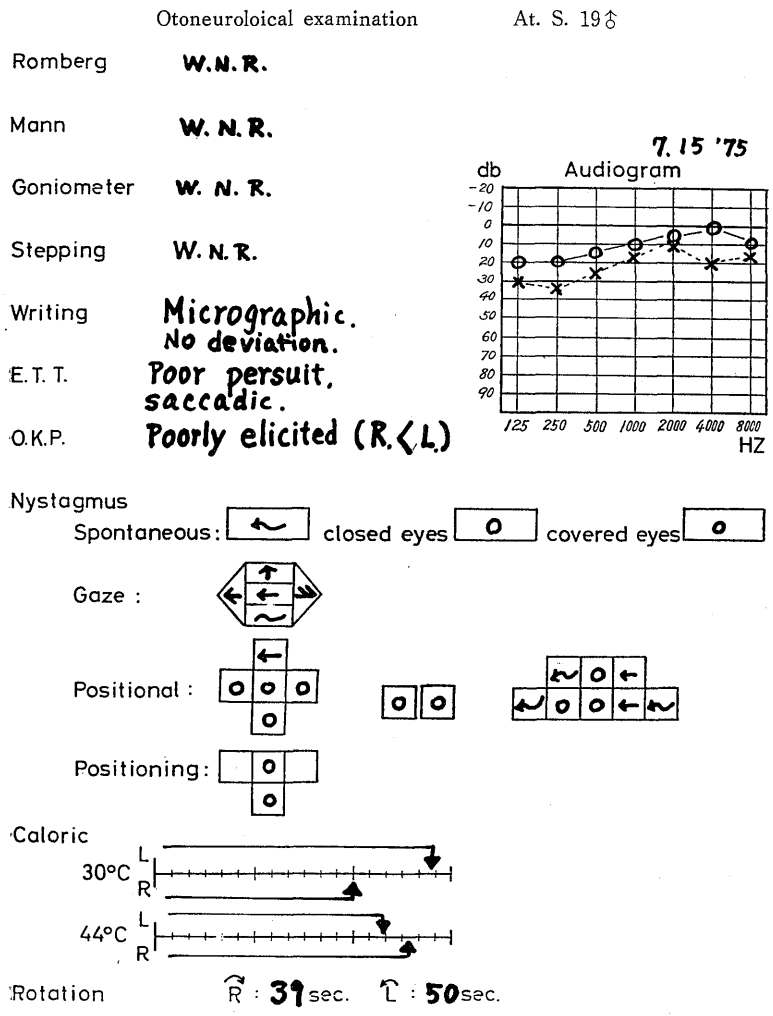


Fig. 14. Data of oto-neurological examination. (Case 2).

N. appeared with weakness of the right abducens n. function suspected. (Fig. 14). As shown in Fig. 12 and 13, this Square Drawing Test revealed marked shortening of length of all lines of square and of the length of Distance 1-4. In particular thing to be mentioned, both figures of SDT with the eyes covered are in symmetrical and not so deviate from the vertical line. Both peculiar findings of micrographic figures on each hand drawing and no notable deviation, small but still symmetrical in figures, will give some impression impirically that a lesion will be around median of the brainstem and impairing slowly and tenderly but progressively.

SUMMARY

Square Drawing Test by each hand (Bimanual Method) is presented for detecting qualitatively and evaluating quantitatively the ataxic disorders.

The test procedures are described in detail.

Results obtained from 30 healthy adults are shown as mean value with standard deviation in each parameter, i. e., 1) length of lines of figures drawn in the prescribed squares, 2) Distance S-E, 3) Distance 1-4, 4) deviation angle. And additionally on 5) derangement of the lines drawn is mentioned.

Data of some cases with dizziness and ataxia are introduced briefly though the following paper will contribute on clinical studies on the Square Drawing Test.

This simple test will be useful as a link of routine oto-neurological test in clinic and field.

Grateful acknowledgement is made to Professor Shoichi Honjo, M.D. for his continuous guidance. And also thanks Toru Sekitani, M.D., Associate Professor, for his helpful discussion and careful review of manuscript.

REFERENCES

1) Fukuda, T.: Vertical writing test with eyes covered. A New Test of Vestibulospinal Reaction. *Acta Oto-laryng.*, 50 : 26-36, 1959.
2) Uemura, T. et al: Clinical studies on Acoustic Tumor (Ⅱ) *Jap. J. Otol.*, 66 : 1549-1556, 1963.
3) Sayk, J.: Der Synergie-Schreibversuch-Ein neue Kleinhirnprufung. *Klin. Wschr.*, 42 : 236-239, 1964.
4) Henriksson, N. G., Dolowitz, D. A. and Forssman, B.: Studies of Cristospinal Reflexes (Latero-torsion) I. A Method for objective recording of Cristospinal reflexes. *Acta Oto-laryng.*, 55 : 33-40, 1962.
5) Spector, M. (Ed): *Dizziness and Vertigo*, Grune & Stratton, New York, 1967.

6) Peiterson, E.: Vestibulospinal Reflexes. Ⅶ. Alterations in the Stepping Test in Various Disorders of the Inner Ear and Vestibular nerve. *Arch. Otolaryng.*, 79 : 481–486, 1964.
7) Zilstorff-Pedersen, K. and Peitersen, E.: Vestibulospinal Reflexes: Spontanous Alteration in Position of Normal Persons doing Stepping Test. *Arch Otolaryng.*, 77 : 237–245, 1963.
8) Emami-Nouri, M.: Vestibularer Reflextonus. *Arch Oto-Rhino-Laryng.*, 206 : 47–55, 1973.
9) Sekitani, T., Honjo, S., Mitani, N. and Shimamoto, K.: Square Drawing Test- A new Quantitative Ataxia Test——*3rd International Symposium of Posturography, Paris, Sept. 1975*, Aggresologie (Paris) (in press)
10) Sekitani, T., Honjo, S., Kobayashi, T. and Shimamoto, K.: Square Drawing Test—A quantitative Test for Ataxia —The 5th Extraordinary Meeting of Barany Society, Kyoto, Oct. 1975. *International J. Equilibrium Res.*, (in press)
11) Unterberger, S.: Neue objektiv registrierbare Vestibularis-Körperdrehreaktion, erhalten durch Treten auf der Stelle: "Der Tretversuch" *Arch. Ohr. Nas. Kehlkopfheilk.*, 145 : 478–492, 1938.
12) Kanesada, K., Sekitani, T. and Mitani, N.: Square Drawing Test—Evaluation of Results of the Test done by each hand—, *Equilibrium Res.*, (in press)