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Abstract

1. Adversive movements were induced by electrical stimulation and metrazol injection on area 4c of the cerebral cortex. 2. The adversive movement from area 4c does not pass through the thalamus, nucleus caudatus, nucleus lenticularis or superior colliculus, but through direct efferent pathways in the internal capsule. 3. The adversive movement from area 4c passes through the pyramidal tract.

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ON THE ADVERSIVE MOVEMENT OF AREA 4C OF THE MOTOR CORTEX

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The first record about the adversive movement is that which FRITSCH and HITZIG[1] described in 1870, in which both eyes faced the opposite side of the stimulation when electrical stimulation was given to the fissura Sylvii. Next, VOGT[2] and FOERSTER[3] reported in detail about the adversive movement characterized by the rotating movements of the head, both eyes, and the trunk.

VOGT[2] classified roughly into two groups the movements which occurred by the electrical stimulation on the brain of monkeys. They are adversive movement and simple contraction. He also divided the cerebral cortex into sixteen areas, and denominated the areas of the adversive movement.

Similarly, FOERSTER[3] divided the cerebral cortex of men into eight areas by electrical stimulation, and reported in detail about the adversive areas. VOGT[2] and FOERSTER[3] presumed that the tract of the adversive movement is the centrifugal tract peculiar in itself from the cerebral cortex. They, however, did not give the answer about the mechanism of the adversive movement or how it occurred.

As concerns whether the adversive movement belongs to the pyramidal or extrapyramidal system, MARSHALL[4] and TOWER[5] reported that the adversive movement might be of extrapyramidal origin because the adversive movement occurred after the interception of the pyramidal tracts.

HAYASHI and MIE[6] studied the motor area of the eyeball, eyelid and ear of dogs, and clarified that these movements are of the extrapyramidal system. JINNAI and OGAWA[7] proved that adversive movement occurred according to the difference of excitement between both sides of the adversive areas. As concerns the path of conduction of the adversive movement, the pathways from areas 5, 7, 19, and 22 pass through the nucleus caudatus and then through the nucleus lenticularis of the same side; the pathways from areas 8 and 6 aβ pass through the thalamus on the same side. All of the pathways go down, without crossing in the cerebral hemisphere, and reach the superior colliculus or the midbrain on the same side. They, thereafter, end at the nucleus of pons on the opposite side. JINNAI and OGAWA[7], however, did not observe that the adversive movement occurred by the stimulation of area 4 c.

We have performed experimental studies to clarify the path of conduction of the adversive movement caused by stimulating area 4c.

MATERIALS AND METHODS

Dogs weighing from 9 to 15 kilograms were used as the experimental material.

Three per cent morphine hydrochloride (0.5 c. c. per kilogram of weight) was used for anesthesia.

1. Method of exposing the cerebral cortex :

A midline incision was made from the forehead to the back of the neck, passing through the occipital protuberance. After the incision, musculus temporalis was stripped from the bone. Parietal bone, frontal bone, and a part of temporal bone were removed by LUER's forceps. It was necessary to open widely portions of the anterior and lateroinferior skull in order to stimulate area 4 c.

2. Method of removing the thalamus :

An incision of about 3 cm. was made along the gyrus entolateralis and reached the lateral ventricle.

The thalamus was removed with a curette.

3. Method of removing the nucleus caudatus :

The lateral ventricle was opened by a method similar to the one used to remove the thalamus. The nucleus caudatus, lying forward and lateral to the thalamus was removed with a curette.

4. Method of removing the nucleus lenticularis :

A curette with a thin handle was inserted 11 mm. deep vertically to the surface of the brain at the site of the sulcus ectosylvius medius. The nucleus lenticularis was removed with the top of the curette by scooping in an elliptical motion. The scooped out area was about 14 mm. anteriorly posteriorly and 11 mm. superiorly inferiorly.

5. Method of removing the superior colliculus :

The front of the cerebellum was exposed by lifting the occipital lobe of the cerebrum with a malleable retractor. The superior colliculus appeared between the cerebrum and the cerebellum. The superior colliculus was removed with a curette.

6. Method of damaging the internal capsule :

A curette with a thin handle was inserted 17 mm. deep vertically to the surface of the brain at the site of the sulcus ectosylvius medius. The internal capsule was damaged by moving the curette up and down 10mm.

7. Laminar coagulation :

A piece of copper was heated 80°C or 70°C and put on area 4c for 6 seconds, 5 seconds, 4 seconds, 3 seconds and 2 seconds. Area 4c was removed one week after the laminar coagulation was done. The degeneration of area 4c was examined by NISSL's staining and hematoxyline-eosin staining.

8. The method of stimulation :

0.05 — 0.07 c. c. of 10 % metrazol was injected intracortically as a chemical stimulant.

Electrical stimulation was made by an apparatus devised by MORI and NUMOTO. The distance between two electrodes is 1 mm. and the time of stimulation is 3 to 5 seconds.

RESULTS OF EXPERIMENTS

1. The results obtained from the stimulation of areas 4 a, 4 b, and 4 c respectively are shown in Table 1.

Table 1

Area Stimulated	Adversive Movement (positive)	Adversive Movement (negative)	Method of Stimulation
Area 4 a	1	9	Electric
	0	10	Metrazol
Area 4 b	0	10	Electric
	2	9	Metrazol
Area 4 c	40	3	Electric
	10	1	Metrazol

When area 4 a was stimulated, adversive movement was observed in one case out of 20 : when area 4b was stimulated, adversive movement was observed in two cases out of 21 ; and when area 4c was stimulated, adversive movement was observed in 50 cases out of 54.

2. Results obtained from the stimulation of area 4c after the removal of the thalamus are shown in Table 2.

Table 2

Number of Experiment	Area Removed	Area Stimulated	Adversive Movement	Method of Stimulation
101	Right Thalamus	Rt. Area 4 c Lt. „	(neg.) (pos.)	Electric
102	„	Rt. „ Lt. „	(pos.) (pos.)	„
103	„	Rt. „ Lt. „	(pos.) (pos.)	„
104	Left Thalamus	Rt. „ Lt. „	(pos.) (pos.)	Electric and Metrazol
105	Right Thalamus	Rt. „ Lt. „	(pos.) (pos.)	Electric
106	Left Thalamus	Rt. „ Lt. „	(neg.) (neg.)	„
107	Right Thalamus	Rt. „ Lt. „	(pos.) (pos.)	„
108	Left Thalamus	Rt. „ Lt. „	(pos.) (pos.)	Electric and Metrazol
109	„	Rt. „ Lt. „	(pos.) (pos.)	„
110	„	Rt. „ Lt. „	(pos.) (pos.)	„
111	Right Thalamus	Rt. „ Lt. „	(neg.) (pos.)	Electric
112	„	Rt. „ Lt. „	(pos.) (pos.)	„

Rt. : right; Lt. : left; pos. : positive; neg. : negative.

When area 4 c was stimulated after the removal of the thalamus, adversive movement occurred in 9 cases out of 12. In two cases out of 12 (No. 101 and 111), no adversive movement occurred by stimulation of the homolateral side of area 4 c after the removal of one side of the thalamus. In one case out of 12 (No. 106), adversive movement did not occur by stimulation on either side.

3. The results obtained from the stimulation of area 4 c after the removal of the nucleus caudatus are shown in Table 3.

Table 3

Number of Experiment	Area Removed	Area Stimulated	Adversive Movement	Method of Stimulation
121	Rt. Nucleus Caudatus	Rt. Area 4 c Lt. "	(pos.) (pos.)	Electric and Metrazol
122	"	Rt. " Lt. "	(pos.) (pos.)	Electric
123	"	Rt. " Lt. "	(pos.) (pos.)	Electric and Metrazol
124	Lt. Nucleus Caudatus	Rt. " Lt. "	(neg.) (neg.)	Electric
125	"	Rt. " Lt. "	(neg.) (neg.)	"
126	"	Rt. " Lt. "	(pos.) (pos.)	Electric and Metrazol
127	"	Rt. " Lt. "	(pos.) (pos.)	"
128	"	Rt. " Lt. "	(pos.) (pos.)	Electric
129	"	Rt. " Lt. "	(pos.) (pos.)	"
130	"	Rt. " Lt. "	(pos.) (pos.)	"
131	"	Rt. " Lt. "	(pos.) (pos.)	Electric and Metrazol
132	"	Rt. " Lt. "	(pos.) (pos.)	Electric
133	"	Rt. " Lt. "	(pos.) (pos.)	"

As Table 3 shows, adversive movements occurred in 11 cases out of 13. In two cases out of 13 (No. 124 and 125) adversive movements did not occur.

4. The results obtained from the stimulation of area 4c after the removal of the nucleus lenticularis are shown in Table 4.

As Table 4 shows, adversive movement occurred in 7 cases out of 10. In two cases out of 10 (No. 143 and 149) no adversive movment occurred

Table 4

Number of Experiment	Area Removed	Area Stimulated	Adversive Movement	Method of Stimulation
141	Rt. Nucleus Lenticularis	Rt. Area 4c Lt. "	(pos.) (pos.)	Electric and Metrazol
142	"	Rt. " Lt. "	(neg.) (pos.)	Electric
143	"	Rt. " Lt. "	(pos.) (neg.)	"
144	"	Rt. " Lt. "	(pos.) (pos.)	"
145	"	Rt. " Lt. "	(pos.) (pos.)	Electric and Metrazol
146	Lt. Nucleus Lenticularis	Rt. " Lt. "	(pos.) (pos.)	"
147	"	Rt. " Lt. "	(pos.) (pos.)	"
148	"	Rt. " Lt. ,.	(pos.) (pos.)	"
149	"	Rt. " Lt. "	(neg.) (pos.)	"
150	"	Rt. " Lt. "	(pos.) (pos.)	Electric

by stimulating the contralateral side of area 4c after the removal of one side of the nucleus lenticularis but adversive movement was seen by stimulating the homolateral side. In one case out of 10 (No. 142) adversive movement did not occur by stimulating the homolateral side of area 4c but occurred by stimulating the contralateral side after the removal of one side of the nucleus lenticularis.

5. The results obtained from the stimulation of area 4c after the removal of the superior colliculus are shown in Table 5.

As Table 5 shows, the adversive movment occurred by stimulating area 4c after the removal of one side of the superior colliculus in all five cases. When both sides of superior colliculus were removed the adversive movement occurred in both cases.

6. The results obtained from the stimulation of area 4c after damaging the internal capsule are shown in Table 6.

Table 5

Number of Experiment	Area Removed	Area Stimulated	Adversive Movement	Method of Stimulation
151	Rt. Superior Colliculus	Rt. Area 4 c Lt. "	(pos.) (pos.)	Electric
152	Both Sides of Sup. colliculus	Rt. " Lt. "	(pos.) (pos.)	Electric and Metrazol
153	Rt. Superior Colliculus	Rt. " Lt. "	(pos.) (pos.)	"
154	"	Rt. " Lt. "	(pos.) (pos.)	Electric
155	Lt. Superior Colliculus	Rt. " Lt. "	(pos.) (pos.)	"
156	"	Rt. " Lt. "	(pos.) (pos.)	"
157	Both Sides of Sup. Colliculus	Rt. " Lt. "	(pos.) (pos.)	Electric and Metrazol

Table 6

Number of Experiment	Area Removed	Area Stimulated	Adversive Movement	Method of Stimulation
161	Rt. Internal Capsule	Rt. Area 4 c Lt. "	(neg.) (neg.)	Electric
162	"	Rt. " Lt. "	(neg.) (neg.)	Electric and Metrazol
163	"	Rt. " Lt. "	(neg.) (neg.)	Electric
164	"	Rt. " Lt. "	(neg.) (neg.)	"
165	Lt. Internal Capsule	Rt. " Lt. "	(neg.) (neg.)	Electric and Metrazol
166	Rt. Internal Capsule	Rt. " Lt. "	(neg.) (neg.)	Electric
167	Lt. Internal Capsule	Rt. " Lt. "	(neg.) (neg.)	Electric and Metrazol

168	Rt. Internal Capsule	Rt. Area 4c Lt. „	(neg.) (neg.)	Electric and Metrazol
169	„	Rt. „ Lt. „	(neg.) (neg.)	Electric
170	Both Sides of Int. Capsule	Rt. „ Lt. „	(neg.) (neg.)	Electric and Metrazol

As Table 6 shows, no adversive movement occurred by the stimulation of area 4c after damaging the internal capsule.

7. The results obtained from the stimulation of area 4c after the laminar coagulation of area 4c are shown in Table 7.

Table 7

Number of Experiment	Laminar Coagulation		Adversive Movement	Method of Stimulation
	Temperature	Time		
171	80°C	6 sec.	(neg.)	Electric
172	„	5 „	„	„
173	„	4 „	„	„
174	„	4 „	„	„
175	„	4 „	„	„
176	„	4 „	„	„
177	„	3 „	„	„
179	„	3 „	not clear	„
180	„	2 „	(pos.)	„
181	70°C	4 „	„	„
182	„	5 „	„	„

sec. : seconds

As Table 7 shows, the adversive movement did not occur after adding heat greater than 80°C for longer than three seconds, but it was observed when heat less than that had been applied.

Histological findings :

1. In one case of laminar coagulation at 80°C for four seconds :

The pia mater was scarred, Layer I had disappeared, and in the area corresponding to it there was round cell infiltration. The round cells also infiltrated around the blood vessels in the medullary substance of the brain, and scar formations were observed in places around the blood vessels. The degeneration penetrated into all the strata of the cerebral cortex. NISSL's granules of the ganglion cells were almost fused, and their nuclei were vesicular. The glial cells had proliferated markedly and had spread to the medullary substance of the brain.

2. In one case of laminar coagulation at 80 °C for three seconds :

The pia mater was scarred, Layer I had disappeared and in the area corresponding to it, round cells had infiltrated. The change from Layer I to Layer III was remarkable. The nuclei of the ganglion cells were reduced in size and fusiform. In places, the nuclei had disappeared. NISSL's granules were reduced and dissolved. The degree of degeneration lessened gradually below Layer III and reached Layer V, but there was no degeneration in Layer VI.

3. In one case of laminar coagulation at 80°C for two seconds or 70°C for four seconds :

The pia mater was scarred, Layer I had disappeared and in the corresponding area, cells had infiltrated. NISSL's granules of the ganglion cells at Layer III were reduced and dissolved in places. The BETZ's cells in Layer V were normal.

DISCUSSION

When areas 4a, 4b, and 4c had been stimulated electrically or with metrazol at strengths not strong enough to produce convulsions, no adversive movement was seen as the result of the stimulation of areas 4a and 4b but advesive movement was seen in a great majority of cases by the stimulation of area 4c.

In order to investigate the pathway of adversive movement occurring by stimulation of area 4c, area 4c was stimulated after the removal of the thalamus, nucleus caudatus, nucleus lenticularis and superior colliculus through which fibers from the adversive area (area 8, 6 aβ, 5, 7, 19, 22) pass, but the adversive movement still existed.

From these results, it appears that the fibers of adversive movement do not pass through the thalamus, nucleus caudatus, nucleus lenticularis, and superior colliculus.

That no adversive movement occurs after injury to the internal capsule proves that the pathway of the adversive movement passes through the internal capsule.

As for the end of the fibers of adversive movement, any conclusion could not be obtained from our experimental studies. It is considered, however, that the fibers probably cross in the midbrain and end at the nuclei of the pons.

VOGT[2] presumed that the tract of adversive movement is the centrifugal tract, peculiar in itself from the cerebral cortex. He did not state whether this centrifugal tract was pyramidal or extrapyramidal or where it ended.

TOWER[5] observed the adversive movement by stimulating the cerebral cortex directly. Several months after cutting the pyramidal tract of cats at the pons, he described adversive movement as belonging to the extrapyramidal system.

HAYASHI and MIE[6] felt that the centrifugal fibers belong to the extrapyramidal system or at least pass through the thalamus because no movement of eyeball and eyelid occurred after the removal of the thalamus. MIE[6], however, did not investigate the adversive movement of area 4 after the removal of the thalamus.

JINNAI and OGAWA[7] observed that adversive movement did not occur by stimulating areas 8 and 6 aβ after the removal of the thalamus but it occurred by stimulating areas 5, 7, 19 and 22. We concluded that the pathway of the adversive movement was from areas 8 and 6 aβ to the same side of the thalamus, to the same side of the superior colliculus of the midbrain ; and from areas 5, 7, 19, and 22 to the same side of the nucleus caudatus, to the same side of the nucleus lenticularis, to the same side of the superior colliculus of the midbrain.

The fact stated above supports the theory that the adversive movement belongs to the extrapyramidal system. But how about area 4c ? It is definite that the pyramidal tract starts from the cerebral motor cortex.

On the other hand, it was also made clear by many scholars (MONAKOW[8], MINKOWSKI[9], MARINESCO[10], BIANCHI u. d' ABUNDO[11], METTLER[12], HIRAZAWA[13], KODAMA[14] etc.) that the extrapyramidal tract started from the cerebral motor cortex (areas 4 and 6). KENNARD[15] and FULTON[16] report that the pyramidal tract starts only from area 4 and the extrapyramidal tract starts only from area 6. The pyramidal tract from area 4 originates from BETZ's cells in the fifth stratum of the motor cortex. If the extrapyramidal tract exists in area 4, it seems to originate from the cells in the sixth stratum or in the fifth stratum excepting BETZ's cells.

Laminar coagulation was tried on area 4 by the method of DUSSER de BARENNE[17] and the relationship between the disappearance of the adversive movement and laminar coagulation in the motor cortex was investigated. The results are as follows : The adversive movement did not occur after heating at 80° C. for three seconds but it was observed when heated at less than 80° C.

The histological findings in this case were as follows : All strata of area 4 were destroyed by heating at 80°C for four seconds. 80°C for three seconds destroyed up to the depth of the fifth stratum. After heating at 70°C for four seconds, strata up to the depth of the third stratum were destroyed, but BETZ's cells in the fifth stratum were found intact.

From these results, for the adversive movement to occur, the function of the fifth stratum is needed even if the cells of the sixth stratum are intact; but if the cells of the fifth statum are degenerated, the adversive movement can not occur.

From the previously stated facts, as far as the advesive movement of area 4c is concerned, it belongs to the pyramidal system.

CONCLUSIONS

1. Adversive movements were induced by electrical stimulation and metrazol injection on area 4c of the cerebral cortex.
2. The adversive movement from area 4c does not pass through the thalamus, nucleus caudatus, nucleus lenticularis or superior colliculus, but through direct efferent pathways in the internal capsule.
3. The adversive movement from area 4c passes through the pyramidal tract.

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