AN EXPERIMENTAL INVESTIGATION OF THE DIRECT PYRAMIDAL TRACT.¹

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INTRODUCTION.

BEFORE entering upon the subject of my paper, I wish to express my thanks to Professor Vaughan Harley for allowing me to carry out this investigation under favourable circumstances at the Laboratory of Pathological Chemistry at University College, and to Mr. Victor Horsley for his assistance, especially during the earlier part of the research, and for the kind and valuable criticism which he was always willing to afford.

The fibres of the crossed pyramidal tract are well known to conduct impulses from the cerebral cortex of one side to muscles upon the opposite side of the body. It has been the object of the present research to determine to what extent the same statement is true for those motor fibres which, at the decussation of the pyramids in the medulla oblongata, do not cross to the opposite side of the cord, but continue on the same side under the name of the "direct pyramidal tract."

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METHOD OF INVESTIGATION.

Animals employed.—Inasmuch as the direct pyramidal tracts form a larger part of the cord in monkeys than in lower animals (and the difference is yet more marked in the case of the *anthropoid* apes), I had hoped and attempted at the outset to carry out this investigation in monkeys. But the necessary severity of the operations and the consequent shock were so great that these animals could not live to the end of the experiment. The same remark applies to cats and to rabbits. The results obtained, therefore, in the present research, are to be taken as applying to dogs only.

In a preliminary note in the *British Medical Journal* of July 18, 1896, allusion was made to an experiment on a monkey which apparently gave positive results. Microscopical examination of the medulla oblongata in that case, however, showed the experimental division to be incomplete.

The following was the method of research:—

(a) The dogs were anæsthetised with ether in all cases except the first, when chloroform was used. In no case was the animal allowed to recover from the anæsthetic.

(b) A preliminary tracheotomy was performed in every case.

(c) The skull was opened over both excitable regions of the cerebral hemispheres without opening the dura mater. All hæmorrhage being arrested, the flap of skin was replaced in order to keep the cortex warm during the progress of the ensuing part of the experiment.

(d) The arches of the atlas and axis were exposed by a median incision and removed. By means of a small trephine, an aperture was made in the thin plate of the occipital bone covering the vermis, and this aperture was enlarged and made continuous with the foramen magnum by removing the bridge of bone, which separated the two.

(e) The dura mater thus brought to view was opened in its whole length, and the cerebellum, lower part of the medulla oblongata, and uppermost end of the spinal cord well exposed. The fourth ventricle was then carefully opened. The posterior median fissure could now be seen

extending down the cord from the point of the calamus scriptorius, with the columns of Goll standing out prominently on each side of it. The cerebellum was raised slightly by means of an aneurism needle and the lower part of the fourth ventricle exposed to view. A von Graefe's cataract knife was then inserted in the middle line just above the point of the calamus scriptorius, and thrust forward and upward towards the anterior surface of the medulla. The incision thus begun was carried in the middle line down the whole length of the medulla, and part of the spinal cord exposed, care being taken that the point of the knife should not quite reach the anterior or ventral surface of these structures. This part of the operation was then completed by withdrawing the knife and inserting into the incision a blunt flat seeker and pressing it against the posterior surface of the basilar portion of the occipital bone, and the posterior surfaces of the bodies of the vertebræ. This proceeding was found to be necessary because, in those cases where one was fortunate enough to strike the middle line in front, the basilar artery became longitudinally divided if the knife alone was used throughout.

(f) At this stage the animal ceased breathing, but was restored by performing artificial respiration for about ten minutes.

(g) Attention was now again turned to the cortex cerebri. This was exposed by again reflecting the flap of skin made at the earlier part of the experiment, and opening the dura mater over each hemisphere. Flaps of dura mater were formed and turned upward, so as to expose on each side the crucial sulcus and neighbouring gyri.

(h) With a weak faradic current, the excitability of the cortex was ascertained by stimulation of the facial area. Satisfied on this point, one next proceeded to systematically stimulate the motor area in all its parts, and to note what movements were obtained as a result of such stimulation.

(2) Finally, the animal was killed, and its brain removed with the upper part of the spinal cord for subsequent examination. The relative accuracy of the division of the decussation was ascertained by macroscopical examination

of the medulla at the time and by subsequent microscopical examination of transverse sections of the same.

EXPERIMENTS.

In the following list of experiments I make no reference to those in which, owing to death of the animal from hæmorrhage, shock, &c., inexcitability of the cortex, or very incomplete division of the decussation, the result was valueless. Unfortunately, owing to the many difficulties of the investigation, much of my work was lost by accidents of this nature.

No. 1.—*Mesial Section.*

In this case, the incision passed longitudinally down the left pyramid and divided all the fibres going from the right hemisphere to the left half of the cord; while the division of those fibres which passed from the left hemisphere to the right side of cord, was incomplete.

Movements obtained.—Flexion of the opposite hip was obtained from stimulation of either cortex.

Flexion of the right fore-limb at the shoulder was obtained from stimulation of the left hemisphere; but no movements could be obtained in the left fore-limb by stimulation of either cortex.

No movements of the trunk could be obtained, nor were there any movements on the same side of the body as the excitation.

No. 2.—*Mesial Section.*

The incision was absolutely in the middle line completely dividing the decussation.

Movements obtained.—Flexion of the opposite hip was obtained from excitation of either cortex. It was equal on the two sides.

There were no movements of the fore-limbs, of the trunk, or of the same side of the body as the excitation.

No. 3.—*Mesial Section.*

The incision passed down the outer side of the left pyramid. It divided all the fibres going from the right

hemisphere to the left side of the cord, but apparently few of those going from the left hemisphere to the right side of the cord.

Movements obtained.—Flexion of the opposite hip was obtained on excitation of either cortex.

Flexion of the right fore-limb at the shoulder was obtained on stimulation of the left cortex.

No movements of the left fore-limb were obtained, or of the trunk, or of the same side of the body as the stimulation.

No. 4.—Mesial Section.

The incision passed down the outer side of the left pyramid, and was such that very few motor fibres were divided.

Movements obtained.—Powerful movements were obtained in all four limbs. I include this faulty experiment, because it not only serves as a control observation, but also because the tail deviated to the same side as the cortical excitation at a spot just above the leg area on each side (*vide Experiment No. 6*).

No. 5.—Mesial Section.

The incision was median and divided the decussation completely.

Movements obtained.—Flexion of the hip, ankle, knee and toes of each side resulted from stimulation of the opposite cortex.

No movements were obtained of the fore-limbs, of the trunk (including the tail), or of the same side of the body as the cortical excitation.

No. 6.—Mesial Section.

The incision passed very slightly to the right of the middle line and divided the decussation completely, except for a few fibres which passed from the left cerebral hemisphere to the right side of the cord at the lower end of the incision.

Movements obtained.—On stimulation of the left cortex a slight movement of the right fore-limb digits was obtained. This was, however, soon lost.

Flexion of the hip, knee, ankle and toes was obtained on stimulation of the opposite cortex on each side.

The tail deviated to the same side as the excitation.

No trunk movements were obtained.

No. 7.—Mesial Section.

The incision was median and completely divided the decussation.

Movements obtained.—The only movements obtained in this animal were slight flexion of the toes on each side on excitation of the opposite cortex; a deviation of the tail to the same side as the excitation. The deviation of the tail was more marked to the left than to the right side.

No movements were obtained of the fore-limbs, or of the trunk, or on the same side as the excitation, with the exception of the tail.

No. 8.—Mesial Section.

The incision was median and completely divided the decussation. At the lower end, however, it deviated to the right and apparently divided nearly all, if not all, of the fibres of the direct pyramidal tract on that side.

Movements obtained.—Slight flexion of the toes was obtained on the right side, but no movements of the left, on excitation of the opposite cerebral cortex.

The tail deviated to the left on stimulation of the left cerebral cortex. No deviation to the right could be obtained.

No movements were obtained of the fore-limbs, or of the trunk on either side.

No. 9.—Mesial Section.

The incision was median for the greater part of its length, but deviated slightly towards the left at the upper end of the decussation, and a few fibres at the upper end of the decussation passing from the left cerebral hemisphere to the right half of the cord escaped division.

Movements obtained.—Excitation of the left cortex gave well-marked flexion of the right hip and knee, slight flexion of the left hip, arching of the trunk laterally with the concavity to the left side and deviation of the tail to the right.

Excitation of the right cortex gave slight flexion of the left hip, knee, ankle and toes, and deviation of the tail to the left.

No movements of the fore-limbs were obtained.

No. 10.—Mesial Section.

The incision was oblique so that it deviated slightly to the left at the upper end, while at the lower end it encroached slightly on the right direct pyramidal tract. A few fibres passing at the upper end of the incision from the left hemisphere to the right side of the cord escaped division.

Movements obtained.—Excitation of the left cortex gave slight flexion of the hip, knee and ankle on the right side, and contraction of the right back muscles so that the trunk was arched laterally with its concavity to the right.

Excitation of the right cortex gave extension of the hip, knee and ankle on the right side. No movements were obtained on the left side.

There were no movements of the fore-limbs.

No. 11.—Mesial Section.

The incision was median and the decussation was completely divided.

Movements obtained.—Flexion of the hip, knee, ankle and toes was produced on each side by excitation of the opposite cerebral cortex, while the tail deviated to the same side as the excitation.

There were no movements either of the trunk or of the fore-limbs.

No. 12.—Mesial Section.

The incision was median and completely divided the decussation.

Movements obtained.—The results were precisely the same as those in the last experiment, except that no movements of the tail were obtained.

REMARKS.

There is considerable uniformity in the results obtained in the above experiments, although No. 9, and in part No. 10, appear to be anomalous in many respects.

In cases 2, 5, 7, 11, and 12 the incision precisely carried out the desired conditions. No. 8 went farther, inasmuch as the only tract left intact was the direct pyramidal tract of one side. In none of these cases was any movement obtained either in the fore-limbs or in the trunk. On the other hand, flexion was obtained, on the opposite side to that of the excitation, at the joints of the hind-limbs in all the cases—hip, knee, ankle, and toes in three, toes only in two, hip only in one.

In three of these cases there was deviation of the tail to the same side as the excitation. Experiments 4 and 6 are also in accordance with this observation; while in the anomalous No. 9 the tail deviated to the opposite side.

In all the other experiments, except No. 4, the crossed pyramidal tract was completely cut off from one side of the body only; and in all these cases the results for that side are in accordance with the above observations.

The movements obtained in the limbs were in no case as powerful as those in a dog where the pyramids are untouched. That this is not merely due to shock is shown by facts observed in No. 4 and in several of my unpublished cases. In some of these the medulla was longitudinally divided; but the pyramids were absolutely untouched. In all such cases the movements of the limbs, obtained on excitation of the cortex, were quite powerful.

No importance is to be attached to the fact that flexion rather than extension of the limbs was so uniformly obtained; because the former movement is so much more readily brought about by excitation of the cortex than the latter.

CONCLUSIONS.

(1) The number of fibres (channels) in the direct pyramidal tract does not appear to be the same for all individuals of the same species.

(2) Nearly all the fibres of the so-called direct pyramidal tract ultimately cross to the opposite side of the cord.

(3) Its fibres convey some of the impulses from the cortex cerebri to the hind-limb of the opposite side.

(4) A few fibres remain on the same side of the cord to supply the tail muscles of that side.

(5) The direct pyramidal tract conveys no impulses to the fore-limbs or to the trunk.