

PYRAMIDAL TRACT

COMPOSITION AND SIGNIFICANCE

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It would be expedient, in beginning this discussion, to establish what is perhaps the simplest definition of the term, "Pyramidal Tract". It is a tract composed of fibres which pass downward through the pyramids on the ventral surface of the medulla oblongata. The simplicity of this definition is striking, but as soon as one begins to meditate on the origin (and consequent function) of these fibres, the simplicity at once disappears and we are faced with a problem of startling complexity.

The study of neuroanatomy during the first trimester of this year left me with the impression that the pre-central gyrus and the pyramidal tract were mutually related—that is, that the former was the origin of the fibres in the latter. This impression reflects the conception that has existed, since 1909, concerning the origin of these fibres. It was then that Holmes and Page May proposed the theory that the pyramidal tract arises exclusively from the Betz cells of the pre-central gyrus. The first shadows of doubt to be cast on this concept fell from the studies of Haggqvist in 1937, who demonstrated that removal of area 4 (the area gigantopyramidalis) from the pre-central region of the monkey did not cause complete degeneration of the fibres in the medullary pyramid. The flame of inquiry and curiosity had been ignited by this spark of doubt and soon the testimony of numerous research workers arose in contradiction to the time-honoured idea, perpetuated since 1909.

Intense investigation of the parietal lobe of the brain culminated in the discovery that a sizeable component of the pyramidal tract (approximately 20%) arose from cells in the parietal cortex. These observations have been confirmed by numerous investigators. Furthermore, it has been demonstrated that approximately 3-4% of the fibres of the pyramidal tract arise from the Betz cells of the pre-central gyrus and that an additional 23-37% of them arise from smaller cells of the same area. Some 50-60% of the pyramidal fibres have thus been accounted for.

The obvious reaction seems to me to be one of speculation concerning the origin of the remaining 40-50% of the fibres. In general the answer to this speculation, that is, a definite answer, remains as yet unsolved. This problem occupies a large

part of research at the present time. Many possibilities as to the origin of the remaining fibres have been suggested from recent research.

Walberg and Brodal claimed to have demonstrated cortico-spinal fibres which arise from the temporal and occipital lobes in the pyramids of the cat. They performed lesions in these lobes and studied carefully the ensuing fibre degeneration. Following such lesions, degenerating fibres could be traced via the internal capsule, the cerebral peduncles, the longitudinal bundles of the pons, the medullary pyramids, and the lateral and ventral cortico-spinal tracts to the lumbar level of the spinal cord. The cord also showed degenerating fibres and collaterals entering the gray matter. Innumerable repetitions of this procedure gave the same results. Although the number of such fibres was not great, the workers believed their presence to be unequivocally demonstrated by such clear cut degenerations.

The possibility that there may be some ascending fibres among the vast majority of definitely descending ones was not considered seriously until the 50's. Lesions were made in the region of the cortico-spinal tracts in the spinal cord of cats. Degeneration of fibres was repeatedly demonstrated in the lateral cortico-spinal tracts, the pyramidal decussation, the pyramids and the peduncles. Initially the lesions were made in the cervical region of the cord, but later the results of lesions made in the mid-thoracic and lumbar regions were studied. These lesions resulted in degeneration of the same fibre bundles as were observed in the initial studies. However, the more caudal the lesion, the more moderate was the number of affected fibres. Nevertheless, even with lesions as low as the fifth lumbar segment, degenerating fibres were clearly demonstrated in sections through the pyramids and the peduncles. Negative findings in the pyramids, pons and peduncles of cats in which the dorsal roots of the sixth, seventh and eighth cervical spinal nerves had been transected proximal to their ganglia helped to prove that the ascending fibres in the pyramid were not primary sensory neurons.

Isolated examples and experiments certainly cannot be construed as being indicative of the normal. However, the workers diligently involved in such experimentation

argue that these findings are not artefacts or random spontaneous degenerations. Their arguments are based on the positive evidence of consistent areas of degeneration when the regions of the lateral and ventral cortico-spinal tracts are damaged, coupled with equally consistent negative findings when the lesions are restricted to other regions of the cord.

It seemed unnecessary for me to seek further confirmation that the "Pyramidal Tract" is generally regarded as one of the most clearly defined and important neural structures existing. In the few preceding paragraphs, I have attempted to show that there now exists solid ground for believing that such a concept may indeed be erroneous and is impeding further progress in the understanding of the neural mechanisms responsible for motor activity. There apparently is no single pyramidal tract arising from the gigantic cells of Betz in the pre-central gyrus, forming the pyramids on the ventral surface of the medulla oblongata, which is responsible for the initiation and control of voluntary muscular activity—that is, the "Pyramidal Tract" as a unified entity does not exist and therefore it would be wiser not to continue to consider it as such.

I should like now to proceed to cast doubt on a topic which is related more or less to the existence of the "Pyramidal Tract" as a unified entity. I speak here of the "Pyramidal Syndrome"—a group of symptoms arising from the destruction of the pyramidal tract. The components of this syndrome are loss of voluntary movements below the level of the lesion, spastic paralysis without atrophy, hyper-reflexes and the sign of Babinski. Evidence against this concept is abundant. It can be obtained from experimental work performed on animals and from clinical material resulting from surgery on patients suffering from hemiballismus, parkinsonian tremor and other conditions characterized by abnormal involuntary movements.

Tower demonstrated that destruction of the "Pyramidal Tract" by section of the medullary pyramids in the monkey and in the cat did not completely paralyse the animal, did not render the pre-central region of the brain inexcitable to electrical stimulation (that is, stimulation of the pre-central region still produced movements of the extremities) and, finally, did not produce a spastic paralysis.

In 1949, Walker reported on the results of dividing the lateral two-thirds to three-fourths of the cerebral peduncle of a woman suffering from hemiballismus. Since the patient recovered with practically no

paralysis, it was at first assumed that the "Pyramidal Tract" had been spared. Another case was reported in 1950 in which parkinsonian tremor was abolished by sectioning the lateral two-thirds of the cerebral peduncle. In this case the patient recovered with very little hemiparesis and it was again assumed that the tract had been spared.

The human cerebral peduncle, as is well known, is divided into three areas depending on the fibre content. The cortico-spinal fibres arising from the pre-central region of the cortex descend in the central portion of the peduncle. The fronto-pontine fibres occupy the medial one-third of the peduncle and the lateral one-third contains fibres at one time considered to be temporo-pontine, which are now suspected to be parieto-pontine.

Operations have been performed in which the lateral and medial one-third of the peduncles were sectioned in order to determine what effect they would have in abolishing conditions such as unilateral parkinsonism or severe dystonic hyperkinesia. Both of these operations proved to be of no value in these conditions, and it seemed logical to conclude that the lateral and medial one-third of the cerebral peduncles are not responsible for the control of voluntary muscular activity (or for the production of these two conditions). Thus it must be the central segment of the cerebral peduncle—that is, the part which contains the portion of the "Pyramidal Tract" which arises in the pre-central gyrus—which must be destroyed to beneficially affect abnormal involuntary movements.

Bucy reports the case of a woman with severe hemiballismus who underwent an operation involving a lesion in the central one-third of her cerebral peduncle. She had experienced wild, flinging, abnormal involuntary movements of the left leg and arm since a very early age. Because of these severe involuntary movements, no useful movements were possible with the left upper extremity—in fact, she sat on her left hand or held it in her right most of the time. The left lower extremity was much less severely involved and she was able to walk quite well. The tendon reflexes were more active in the left lower extremity than in the right, but they could not be tested in the left upper extremity because of the uncontrolled involuntary movements. Babinski's sign was not present. Immediately following the operation, the patient had a complete left hemiplegia and the abnormal involuntary movements were absent. Within a few hours voluntary movements began to return and continued to improve in strength and extent. About three

weeks after the operation a slight tremor became evident during movements of the left arm. The abnormal involuntary movements increased until they were approximately 25% as severe as before the operation. Volitional movements were of full range and normal strength. The patient had free movement of the thumb and fingers individually or together, permitting her to perform such tasks as holding vegetables with the affected hand while peeling them with the right hand or holding a piece of cloth while it is being hemstitched. There was no spasticity. Tendon reflexes on the left were mildly hyperactive, as they were before the operation. Babinski's sign appeared on the left immediately after the operation and persisted.

Several other patients have undergone similar operations. Although the degree of success in achieving a cure for these conditions varied among patients, nevertheless, certain prominent features such as lack of spasticity, continued voluntary movements, etc., could be demonstrated in each case.

The results of these operations, in the light of what was once believed, are truly remarkable and revolutionary. It would seem that destruction of the cortico-spinal fibres arising in the pre-central gyrus does not result in a spastic paralysis of the con-

tralateral extremities. The most notable features are a lack of spasticity, little or no increase in tendon reflexes and the appearance of Babinski's sign. In the case discussed, it might particularly be noted that the discrete usage of the musculature, especially of the digits, is not lost. However, before we ride the pendulum too far over to the other side, it must be said that these patients are not entirely normal so far as control of their skeletal musculature is concerned. The problem of restoring these people to the normal state is not the case in question here. The main point is that our previous notions of the functions of the cortico-spinal fibres arising from the pre-central gyrus appear not entirely correct.

Thus, briefly in conclusion, there appears to be firm ground for suspecting that there is error in believing in the existence of the "Pyramidal Tract" as a unified entity. Associated with this, the classical conditions which are supposed to result from a lesion of this tract are also open to criticism. These observations indicate that attempts should be made to clarify and establish the origin, termination and function of the various components of the medullary pyramids, referring to them as such, and thus replacing the term "Pyramidal Tract".

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