INACTIVATION OF VOLUNTARY MOTOR FUNCTION
FOLLOWING RHIZOTOMY

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The sensory aspect of motor physiology seems to have been neglected experimentally, most of the investigations in this field having been concerned with studies of the central area of the cerebral cortex or its pyramidal projection. One viewpoint, in this respect, is that the initiation and direction of voluntary motor activity does not actually originate in the motor cortex but is dependent upon sensory perception: visual, auditory, olfactory, taste and general sensory acting in combination with previously stored-up impressions (Buchanan, '48). Gooddy ('50) has elaborately stressed the possible significance of all types of afferent impulses in volition stating that sensation and motion form a single, indivisible, and continuous process. He believes that the motor cortex is taught to perform movements by receptors and that no sharp division exists between motor and sensory function.

If volition depends upon a continuous flow of impulses coursing over a series of afferent, intercalated and efferent neurons (including those associated with the motor cortex), then injury to any one or more of the three groups should produce motor deficit varying with the degree and location of the involvement. The purpose of the present investigation is to determine the defects produced by total brachial rhizotomy in the monkey. Such a procedure abolishes all of the incoming general sensory impulses including the afferents from muscles and provides an opportunity to study how the motor cortex and other motor cells may react in their absence.

The results of a few past investigations indicate that the collective neuronal impulses, coursing over the dorsal roots, are of major significance. Sherrington and Mott (1895) reported that rhizotomy in the monkey causes more serious motor deficits than when the motor cortex itself is excised. Cutting the dorsal roots is also known to modify spasticity even that of the decerebrate type (Fulton, '48). In this respect, some of the pioneering neurosurgeons tried rhizotomy for the alleviation of spasticity (Frazier, '10); Spiller and Frazier ('10); Foerster ('13)). If section of the dorsal roots modifies spasticity then impulses coursing over them may play a role in producing this condition in lesions involving certain parts of the brain and spinal cord.

MATERIAL AND METHODS

The left dorsal roots from cervical two downward to thoracic four inclusive have been sectioned in 13 monkeys, 12 adult and 1 infant (4 weeks of age). The animals, in each case, were examined at weekly intervals for as long as 8 months (the average being about 16 weeks) both in and out of their cages. In the operations, great care was exercised in order

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not to nick the spinal cord in the region of the pyramidal tract which is located in the posterior part of the lateral funiculus immediately adjacent to the posterior roots. The numerous rootlets were cut with iridectomy scissors with the points directed laterally in order to minimize this possibility. In a few instances, however, the pyramidal tract was found at autopsy to be degenerated partially on the operated side. It was also found that in some instances the experimental adult animals could not be kept profitably much longer than 4 months postoperatively because regrowth of bone and connective tissue around the cord gradually caused pressure symptoms. These did not, however, mask the motor symptoms in the affected but rather in the normal extremities, and particularly the legs. This was not true of the infant monkey who had no signs of pressure symptoms 8 months postoperatively.

Just before sacrifice, the motor cortex opposite to the dorsal root lesions was exposed as well as the isolated ventral roots on the operated side and stimulated by a 60 cycle sine-wave stimulator to determine the electrical reactions.

Finally, the completeness of the lesions of the dorsal roots was determined grossly at autopsy and the extent of the degeneration within the roots and spinal cord microscopically by means of silver stains.

RESULTS

When all the dorsal roots to an upper extremity in the monkey are sectioned, the overall motor deficit produced in the involved striated muscles is immediate, profound, enduring and of a uniformly characteristic type. Paralysis is almost complete, only the crudest possible motion being retained. This latter consists of rare, random, and aimless movements generated at the shoulder joint. Stimuli of emotional origin are capable of breaking through the lower motor neurons only on violent struggling. The animal does not use the affected extremity in any postural or skilled movements. It is not employed in supporting the body weight in the sitting position, for progression, for grasping the wire meshes of the cages, for climbing or for eating. For these conditions to develop, it is essential that all the posterior rootlets of the brachial plexus be cut as even small remnants left behind during the operation may allow a surprising range of movement.

The character of the paralysis is flaccid. In moving around the cage, the affected upper appendage swings pendulously back and forth. On testing the animal while it is seated in a chair, little or no tone can be detected and the member falls as a dead weight when released from an elevated position indicating a lack of checking action.

In respect to the reflexes, the biceps and triceps tendon jerks and the grasp reflex are abolished. It was noticed, however, that the capacity to perform the scratch reflex remains unaffected. The cross-extension and other reflexes were not tested.

The above defects are enduring and there is little capacity for restitution of normal function. At least this seems to be true for as long as 4 months, the maximal time the individual experiments on adult monkeys were conducted.

An infant monkey, about 4 weeks of age, still in the suckling stage and unable to walk or perform skilled movements of any kind, was kept and studied for 8 months, following section of all dorsal roots from C3 to T4 on the left side. During this comparatively long period, the motor deficits are found to be much the same as those described for the adult animals in respect to reflexes, tone and movement. Random and aimless movements with clenching of fist are prevalent while still in the suckling stage. Very gradually and almost imperceptibly over a 6 months' period some shoulder motion develops so that it can direct the involved arm into the openings in the cage during the process of climbing up and down. At no time did he perform finger movements of any kind. Some slight postural support is occasionally noticed when it rests on the dorsum of the affected wrist. Six months after the operation a test was made in which the animal's right arm was tied to his body which resulted in an inability to climb the sides of the cage. He can reach and partially grasp the meshed wires but cannot boost himself up, even partially, due to lack of strength or control. He fell down twice and remained on his back helpless for about 5 minutes on each occasion.
One of the characteristics of the investigation is that, in the animals which have a severe paralysis produced by section of all the dorsal roots to an extremity, the motor cortex (area 4) remains viable and the muscles respond actively at low thresholds of electrical stimulation (0.5 to 2.0 volts). The same is true for the ventral roots on the operated side.

COMMENTS

On the basis of the results obtained, the collective impulses coursing over the dorsal roots from an extremity in the monkey seem to be highly important in all phases of its voluntary motor activity including posture, tone, and movement. Very close to the maximal defect is immediately and more or less permanently produced when all the posterior radicles of the brachial plexus are sectioned. The paralysis is flaccid and remains so. To obtain this phenomenon, it is important that every rootlet be cut, otherwise phases of function will persist. The motor cortex, although viable and highly responsive electrically, is helpless in initiating and directing anything but the crudest and most useless type of movements. This may be due either to the lack of afferent connections from the peripheral receptors to the cortical motor cells or to the anterior horn cells or possibly to both. Still other centers may be affected. Sensory root impulses thus seem to have a highly excitatory and continuous priming effect on pertinent motor cells within the central nervous system. It can be surmised that a monkey would be a totally incapacitated animal as far as its muscular system is concerned with all afferent fibers over the craniospinal root system destroyed.

The afferent impulses coursing over the dorsal root system also seem to be of primary importance in ontogenetically training the motor centers within brain and spinal cord to function adequately in voluntary movement. At least, successful control does not develop during the first 8 months of infancy in the monkey in their absence although the motor cortex and ventral root system may be normal. This conclusion is based on the study of one baby monkey.

The restitution of motor function which occurs following lesions in the central nervous system may be due largely to the manner in which afferent impulses flowing over the “root system” act on remaining, uninvolved normal tissue. It seems possible that no regaining of motor physiology would occur in the absence of these impulses. Kennard and Kessler ('40) reported practically complete recovery of all aspects of motor function within a week following extirpation of area 4 in an infant monkey (age 4 weeks). No such remarkable restoration occurs when all the dorsal roots are successfully cut to an upper extremity in the same species of animal of the same age. In the experiment conducted in this investigation, very little recovery of the severe motor deficits produced was noted over a period of 8 months at which time the animal was sacrificed. The same is true for adult animals. The dorsal root lesions produce a more enduring and severe interference with movement than do isolated cortical lesions of the Rolandic area in the monkey. Denny-Brown ('50) has postulated that lesions of the motor cortex cause a “depression” of function rather than a true loss of any specific movement or power of contraction of particular muscles principally because of a characteristic rapid restitution of function. It is believed that dorsal root lesions cause changes which do not fall into the
same category, the deficits have a more permanent character and are of a different quality.

Another consideration which apparently has received scant attention is the possible role of root impulses in the production of spasticity following lesions of the brain and spinal cord. Spasticity may be due primarily to the manner in which afferent impulses affect a pathologically changed central nervous system. Cutting all of the dorsal roots modifies any form of spasticity even that of decerebrate rigidity (Fulton, '48), therefore, it may play a part in producing it. Some of the pioneering neurosurgeons who tried rhizotomy for the alleviation of spasticity knew from experience that it was advisable to cut all the dorsal roots to an extremity because it converted the spastic to a purely flaccid type of paralysis (Frazier, '10; Spiller and Frazier, '10; Foerster, '13). Therefore, partial section was always employed.

If lesions which involve the roots, in their entirety, cause such a profound and characteristic type of paralysis, then it seems plausible to conclude that pathological involvement of any of the sensory tracts within the central nervous system of man may also impair voluntary motion to some degree. Sensory impulses entering the spinal cord and brain stem are "distributed" to the cerebellum, cerebrum, and other motor cells by various routes. This view might explain, at least in part, the many paralytic cases found in which the pyramidal tract axons were normal and undegenerated (Bielschowsky, 1916–1918; Finkelnburg, 1913; Hoestermann, 1912; Lassek, 1944, 1945, 1946, 1950; Rhein, 1913; Spielmeyer, 1906).

In concluding, it seems that the results of the present investigation permit the assumption that afferent impulses passing into the central nervous system over the "root system" may be of such importance that they ramify into every phase of volition.

CONCLUSIONS

The dorsal roots to an extremity, in their entirety, play a significant role in the overall performance of voluntary motor function ramifying into all phases: movement, tone and reflexes. When they are sectioned, severe and enduring deficits result characterized by an almost complete loss of all purposeful movements. Flaccidity is a predominant feature, and many reflexes including the postural are affected. Impulses, coursing over this system, seem to have a "priming" effect on motor cells within the central nervous system, without which initiation and direction of motor phenomena is impossible.

It is believed also that the dorsal root system, in toto, plays an important part in ontogenetically training upper and lower motor neurons to function normally and in the restitution of function and production of spasticity following lesions of the central nervous system.

REFERENCES


RHIZOTOMY AND MOTOR FUNCTION


