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## SPASTICITY: PHYSIOLOGIC AND NEUROSURGICAL CONSIDERATIONS WITH PRELIMINARY REPORT OF TWO CASES

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Spasticity is a condition of the musculature identified by partial or complete paralysis and increased resistance to movement associated with hyperactivity of the reflexes of the tendon and periosteum. The control of discharges going out over "the final common pathway" to produce normal muscle tone is a fine adjustment of many descending impulses arriving at the anterior horn cell, a summation of those from the cortex, basal ganglia, reticular substance, tegmentum, and cerebellum. In the surgical treatment of spasticity four distinct methods have been utilized: excision of the cerebral cortex, resections at lenticular level, cordotomy, and resection of the spinal nerve roots. This paper will discuss these procedures and present the results in two cases treated by cordotomy.

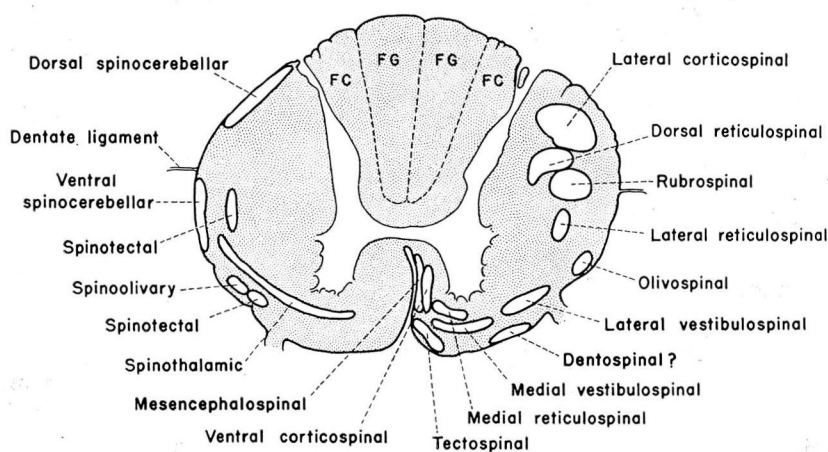
Knowledge of the pathologic process that brings about spasticity is far from complete. It has been shown that changes in muscle tonus can be produced by lesions in cortical areas 4, 6, and 4s, as well as in certain portions of the basal ganglia, reticular substance, tegmentum, cerebellum, and spinal cord.

Physiologically there is a wide diversity of opinion as to the mechanism producing spasticity. In the opinion of the authors it appears advisable to consider that increase in tonus is not always due to a release phenomenon but often to a predominance of one group of descending pyramidal and extrapyramidal impulses over another, or as Magoun has phrased it, "spasticity results from combined disturbances of extrapyramidal innervation." Hence, when attempting surgically to alter the tonus of muscle groups, we must consider all the descending impulses impinging on the anterior horn cell, the inhibitory as well as the excitatory (Bodian, Magoun, Hines, Murphy and Gellhorn).

The next consideration is the anatomic location of the extrapyramidal and pyramidal tracts. Putnam has postulated that there are two groups of descending extrapyramidal pathways. The first "lies just anterior to the crossed pyramidal tract, and extends mesially as far as the gray matter." The second "lies along the periphery of the cord in the anterior quadrant." We are including a semi-diagrammatic chart of the well established and also controversial pathways (figure). Of these we feel that the reticulospinal tracts, a possible direct cerebellar, and a portion of the rubrospinal tract are the most important efferent pathways, while the ventral spinocerebellar is the most important afferent. To date, Papez' work on cats is probably the best available complete work on the origin of these pathways.

Bodian has recently shown that extensive neuron destruction occurs in the reticular formation of the lower brain stem in cases of acute poliomyelitis in monkeys which were sacrificed shortly after the appearance of generalized spasticity. He postulated that destruction of the inhibitory mechanism located there "was at least in part responsible for the spasticity of poliomyelitis", adding corroboration to Magoun's suggestion that spasticity was largely dependent on injury to the pathways arising in cortical area 4s and extending to the reticulospinal centers in the brain stem.

With this evidence in mind it seems safe to assume that one of the reticulospinal tracts acts to decrease muscle tone. The influence of the cerebellar nuclei has been discussed (Kleist, Bonhoeffer, Snider and Stowell, Delmas-Marsalet and van Bogaert), but the pathways over which the descending cerebellar impulses travel to produce "discrete"



Spinal Cord Segment T II

movements are not known. The situation is undoubtedly much more complicated than even our present knowledge indicates, especially when we consider the part played by "the diffuse mechanism of conduction known to exist in the gray matter of the spinal cord" (Rasmussen).

We believe it advisable to include the spasticity of acute poliomyelitis and spinal cord lesions, along with the three most common types of spasticity: hemiplegia, paralysis agitans, and the athetoid-dystonic group. In these syndromes there is a common denominator of increased muscle tone, although the amount of paresis and hyperkinesia and hypokinesia is variable.

Conservative methods of therapy directed at alleviating the disorders of spasticity have in general proved disappointing. Muscle re-education has been the basis of treatment in cerebral palsies (Phelps, Carlson). Curare (West, Burman) and more recently prostigmine (Kabat and Jones, Eveleth and Ryan) have helped materially in lessening the tone of spastic muscles and also in decreasing the amplitude and frequency of muscle spasms. With recent physiologic advances and improved surgical technics, however, interest has been growing in the attempt to alter the tonus of muscle by operative procedures. The report of Scarff and Pool on the advantages of posterior column resections in flexor spasms is the most recent.

The first surgical procedure to relieve spasticity was performed in 1909 by Sir Victor Horsley, who excised the motor cortex successfully for the relief of athetosis. The removal of cortical areas was repeated with beneficial results by David and Hecaen, Sachs, Bucy and Buchanan, Bucy and Case, and Klemme. Unsuccessful operations were listed by White, Foerster, Browder, and Davison and Goodhart. Klemme's series is by far the largest, and many of his cases were benefited when measured by the effect on the hyperkinetic phenomena. Mashanskiy, Nasaroff, and Naffziger injected alcohol into the motor and premotor areas with variable results.

Russell Myers introduced a second approach at the lenticular level. He first removed a portion of the caudate nucleus and later revised his operation to interrupt the pallidofugal fibres. He obtained good results in abolishing the tremors and rigidity of paralysis agitans.

The posterior roots were sectioned for tremor by Foerster and Gagel, and Pollack and Davis, and the posterior columns by Rizzatti and Moreno, and Scarff and Pool. In Scarff and Pool's report the results were excellent in alleviating spasms.

In 1931 Putnam first divided the anterolateral columns for athetosis, and this procedure was subsequently repeated by Oldberg, Mashanskiy, and Toennies. Putnam later cut the lateral pyramidal tracts in cases of

paralysis agitans with successful results. In one of Putnam's cases of anterolateral column resection there was partial relief of rigidity.

Lesions produced in the dentate nucleus reduced the rigidity of paralysis agitans but increased the tremors (Delmas-Marsalet and van Bogaert). The effect of sympathectomy will be discussed in a later paper.

## Case Reports

**Case 1.** A white man, aged 24, was admitted to Cleveland Clinic Hospital complaining of weakness in the legs of four years' duration. The present illness had started gradually with loss of power in the right foot. With the progressive weakness there were associated involuntary movements and stiffness of both lower extremities. The patient had had a kyphosis and scoliosis for many years.

Neurologic examination demonstrated that the patient was unable to walk without support. The cranial nerves showed no abnormalities, and sensation and motor power of the upper extremities were normal. The legs were extremely spastic, and extensor and flexor spasms were precipitated by a minimal stimulus. There was hypalgesia of stocking type over the legs and feet.

Myelogram was carried out, revealing a partial block at the upper margin of the second thoracic vertebra. Laminectomy revealed rotation of the cord with apparent stretching. A diagnosis of congenital scoliosis with cord compression was made.

Cordotomy was then performed at the second thoracic dermatome, and the left anterolateral column was divided, the cord being resected for a depth of 4 mm. from the dentate ligament ventrally to a point 0.5 cm. anterior to the exit of the motor roots. Following operation the patient had less spasticity and fewer muscular spasms in the left leg. There was no involvement of the pathways subserving bladder function, and there was analgesia to the fifth thoracic dermatome on the right. The patient had an uneventful postoperative course and was discharged to return in three months for resection of the right anterolateral column.

The first case was admitted to the hospital on account of severe flexor and extensor spasms of both extremities. Prostigmine by mouth, intramuscularly, and intrathecally had offered only transient incomplete relief. There was improvement (approximately 30 to 50 per cent) in the spasms and spasticity after the cordotomy.

**Case 2.** A woman, aged 25, was referred to the Clinic on February 7, 1946, by Dr. Paul B. Stewart of Warren, Pa., complaining of severe pain in both legs and thighs. The patient had started to use a walker at the age of 8 and had never been able to walk normally. A diagnosis of spasticity due to cerebral birth injury was made. In March, 1945, she had started to have attacks of "drawing of the legs" which were associated with severe pain requiring large doses of opiates. She had been confined to bed. A fasciotomy produced no relief, and the patient as a last resort was referred to the hospital for cordotomy.

The patient presented the typical picture of dystonia affecting the head, arms, and legs. She was unable to walk. The head had an irregular tremor or jerking when she talked or became excited. The arms had athetoid movements, greater on the right than on the left, which were increased by effort or emotion. The legs presented an amazing picture, both being "drawn-up under her" in extreme flexion. During periods of excitement or while the patient was lying comfortably there were flexion spasms involving the biceps muscle group of the thighs and the gastrocnemius-soleus group of the legs, and

she would grimace with pain. Sensation was normal, and all reflexes were hyperactive with Babinski reflexes present bilaterally. Both knee joints were almost fixed. Laboratory studies revealed *Escherichia coli* cystitis. The patient had control of bowel and bladder.

Curare intravenously gave no relief, and therefore an anterolateral cordotomy was performed on the right side at the second thoracic dermatome. The scalpel was inserted 5.0 mm. just anterior to the dentate ligament and carried forward and laterally to section the anterolateral column, the blade being withdrawn at the exit of the anterior roots.

Following operation there was relief of pain in both legs. The spasticity and flexor spasms had completely disappeared in the right leg, and the left leg was analgesic.

Three months later the patient had no pain in either leg and stated that she was able to move the right foot better than the left. Examination five months later showed that the tonus of the right leg was definitely less than the left.

This case represented one of the athetoid-dystonic group. The patient had been referred mainly because of severe pain in both lower extremities, greater in the left leg. Right anterolateral cordotomy was carried out to relieve the pain of the left leg, and it was hoped that by sectioning the ventral spinocerebellar and one of the reticulospinal and descending cerebellar pathways, the spasticity of the homolateral leg would be alleviated. Following operation the patient was entirely free from pain in the right leg due to complete relief of the spasticity and flexor spasms and in the left leg due to analgesia.

Evidence has been presented that neurosurgical procedure directed against spasticity will become of greater and greater benefit as our knowledge of the anatomy, physiology, chemistry, and pathology of the nervous system increases, and will be of distinct advantage in supplementing the pharmacologic and the physiotherapeutic approach. No conclusions can be drawn from the cases reported, but they suggest that cordotomy can favorably influence spasticity.

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## TREATMENT OF CEREBRAL PALSY

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In 1862, Little<sup>1</sup> described a group of children suffering from spastic paralysis. Most of them were thought to be hopeless idiots, although it appeared worthy of mention that some of the children showed evidence of normal intelligence. The possibility of treatment was not considered.

Since that time, however, many patients have benefited by treatment for cerebral palsy.

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