Central Mechanisms for Recovery of Neuromuscular Function

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In treatment of paralysis of various types by means of therapeutic exercise, the role of the muscle is usually considered predominant while the important role of the central nervous system in recovery of voluntary motor function is often overlooked. This point of view is evident in two recent reviews (*7, 9*).

Physiologists have long known that after lesions of the central nervous system, functional recovery may occur to a considerable extent despite permanent anatomical destruction of an essential motor pathway, such as the corticospinal tract. This recovery is believed to occur through a process of compensation by which other intact pathways, largely extrapyramidal, substitute for or take over the function of the damaged tract (*2*). The process of compensation is considered to occur spontaneously. From our study of several thousand patients, with various types of paralysis, undergoing intensive neuromuscular rehabilitation, it has been possible to demonstrate that substitute pathways for voluntary motion can be developed rapidly and effectively through training. New techniques applied in neuromuscular reeducation have shed light on the predominant role of central neural mechanisms in recovery of motor function (*5, 6*). The use of these techniques has also clarified the fundamental functions of the major motor mechanisms in the central nervous system.

A basic component of the technique of muscle reeducation in paralysis is maximal effort by the patient to contract paralyzed muscles against the resistance of the therapist. It was found, however, that the response of the paralyzed muscles could be further increased to a marked degree by a number of mechanisms which facilitate central stimulation and apparently produce summation of subliminal impulses in the motor centers. These mechanisms are:

(1) *Mass movement patterns* (*5*). These include adversive movements and other complex patterns which are still available for central stimulation after almost complete destruction of both corticospinal tracts. These patterns presumably function through extrapyramidal mechanisms. An example of such a pattern in the lower extremity is: flexion, adduction, external rotation of the hip; flexion of the knee; anterior tibial and extension of the toes. Even though the anterior tibial is completely paralyzed from a corticospinal lesion, it will contract and dorsiflex the ankle as a result of overflow of energy through the total central pattern from the better innervated hip and knee muscles contracting maximally against resistance.

Gellhorn (*3*) showed that a similar specific functional association can be demonstrated in the monkey between the triceps and the flexor carpi, between the hamstrings and anterior tibial, etc. When the motor cortex to the hamstrings is stimulated, the anterior tibial is also facilitated. The motor points for synergic muscles are adjacent on the surface of the cortex.

It is our contention that the basic voluntary motions are specific mass movement patterns, resulting in simultaneous synergic movement throughout the limb from its proximal to its distal end, with specific synergic components of the trunk musculature also entering into the total pattern. Isolated motions are apparently derived from these fundamental patterns. These same mass movement patterns are evident in normal activity, i.e., in heavy work and sports such as chopping wood, kicking a football, pitching a baseball, etc. In addition to facilitation of voluntary motion, maximal stimulation of these patterns results in marked and prolonged relaxation of spasticity, muscle spasm, and Parkinsonian rigidity.

(2) *Reflexes* (*5*). Placing a paralyzed muscle under greater tension by stretching will often increase the response in voluntary contraction of that muscle. In hemiplegia, the voluntary contraction of the paralyzed hamstrings for knee flexion is markedly factilitated in the sitting position when these muscles are placed on stretch. Stretching the anterior tibial will also increase the response of the whole lower extremity mass movement pattern, not only in the ankle, but in the knee, hip, and lower trunk muscles as well. Gellhorn (*3*) found a similar phenomenon on cortical stimulation in monkeys. Stretch of the triceps greatly increases the response of that muscle to stimulation of the motor cortex. Also stretch of the extensor carpi increases the response to cortical stimulation, not only of that muscle but of the synergistic biceps as well. Furthermore, he showed that subthreshold stimulation can produce a response in a stretched muscle by summation of the weak cortical with stronger proprioceptive impulses.

Other reflexes can also summate with voluntary effort to produce contraction in paralyzed muscles, i.e., the mass flexion reflex of the lower extremity (von Bechterew), tonic neck reflex of Magnus, gag reflex, etc.

(3) *Quick reversal of antagonists.* In this technique, the antagonistic motion is carried out against maximal resistance, and then suddenly the agonist motion is performed as rapidly and strongly as possible. This method of facilitation summates with mass movement patterns for still greater response. Quick reversal of antagonists is evident in normal activity in chopping wood, the boxer's punch, the golf swing, the farmer using the scythe, the football kick, etc. The fundamental mechanism involved was demonstrated years ago by Sherrington and termed ''successive induction,'' i.e., stimulation of the flexion reflex strongly facilitates an antagonistic extension reflex in the same limb immediately afterward.

The technique of quick reversal has been especially useful in patients with lesions affecting function of the cerebellar hemispheres.

(4) *Rhythmic stabilization* (*6*). In this technique, the patient attempts to hold a rigid position and the therapist alternately and rhythmically applies maximal resistance in an attempt to move the limb. As an ex-

ample, the patient holds the wrist rigid in the neutral position and the therapist alternately and rhythmically applies resistance to the wrist extensors, then the wrist flexors, then extensors, and so on. The patient is alternating isometric contractions and, as the procedure is continued, the power of the isometrically contracting muscles increases. This technique is applied in mass movement patterns and the resulting summation of central stimulation greatly increases the voluntary contraction of paralyzed muscles. There is usually an afterdischarge following rhythmic stabilization. This technique not only markedly facilitates voluntary contraction of paralyzed muscles but also inhibits spasticity, muscle spasm, or rigidity.

This method also utilizes the principle of successive induction but with alternating isometric contraction of the muscles. Patients with many different types of paralysis including lesions of the corticospinal tracts, of basal ganglia (including Parkinson's disease and athetosis), and of lower motor neurons responded remarkably to this technique. On the other hand, patients with even a slight degree of cerebellar involvement failed to carry out rhythmic stabilization successfully. In fact, application of rhythmic stabilization was a very sensitive test of cerebellar function. It became apparent that the cerebellum is probably an essential part of the central mechanism for rhythmic stabilization.

A careful study of a large number of patients, with cerebellar disease from multiple sclerosis or familial cerebellar ataxia, revealed that the disability correlated closely with the deficiency in carrying out rhythmic stabilization but failed to correlate at all with the degree of paralysis of the muscles. It soon became apparent that the intention tremor, hypotonia, dysmetria, rebound, and marked fatigability in these cases was related fundamentally to a deficiency in power, range, and particularly endurance of isometric voluntary contraction of individual muscles. The inability to perform rhythmic stabilization by alternating isometric contraction of antagonists was related to a more basic deficiency of isometric contraction of each antagonist individually. Isotonic voluntary contraction was involved much less, if at all. This hypothesis has been tested by treating patients with the cerebellar syndrome by developing the power, range, and duration of isometric contraction of the affected muscles. For this purpose, the quick reversal technique combined with mass movement patterns against maximal resistance was particularly effective. It has been possible to demonstrate that this procedure improves and may in some cases completely eliminate the cerebellar syndrome and its attendant disability. As the deficiency in isometric contraction improved, the ability to perform rhythmic stabilization also improved, and the whole syndrome of asynergia, including intention tremor, dysmetria, rebound, hypotonia, and fatigability was benefited concomitantly. This is the first effective therapy developed for the cerebellar syndrome and also the first time that isometric contraction was implicated as the basic deficiency involved (*1, 2, 4*). From these observations, it is reasonable to set up the hypothesis that the fundamental function of the cerebellar hemispheres is to facilitate voluntary isometric muscular contraction.

The function of the corticospinal mechanism appears to be stimulation of voluntary motion and inhibition of spasticity. Spasticity is dependent on the stretch reflex and facilitating postural mechanisms in the reticular formation and vestibular nuclei (*8*). An analysis of Parkinson's disease suggests the possibility that the area in the basal ganglia, damage to which produces this syndrome (substantia nigra and globus pallidus), has the fundamental function of facilitating isotonic voluntary muscular contraction. There is evidence that the cerebellum has the opposite effect of facilitating voluntary isometric contraction. The deficiency in Parkinson's disease, aside from the tremor, appears to be related to weakness, slowness, fatigability, lack of range, and difficulty in initiating isotonic voluntary motion. Isometric contraction is carried out much more strongly and rhythmic stabilization is performed effectively. Improvement in voluntary isotonic contraction through application of mass movement patterns and rhythmic stabilization has significantly improved the disability, accompanied by striking improvement of rigidity.

References

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