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RESPONSE TO STRETCH OF HYPERTONIC MUSCLE GROUPS IN HEMIPLEGIA*

BY

J. BREWSTER BRENNAN, M.D., D.Phys.Med.
*Department of Physical Medicine, St. James's Hospital,
 London*

A chance observation provided the stimulus for the work presented. A man with hemiplegia of one year's duration was fitted with a splint to prevent contracture of his knee, which was habitually held in 90 degrees flexion by marked tonic spasm. The splint held his knee in full extension. Next seen a month later, he gave the history that he had worn it constantly during that time. He had found it comfortable to wear and it had enabled him to walk, so he had not risked its removal, fearing his spasm might return. On examination of the limb it was found that hypertonus in the hamstrings had been abolished and that voluntary extension, previously absent, could be performed against resistance. Tonus in the quadriceps, originally mild, had become appreciable, but voluntary flexion had not been much affected.

He had had no other treatment during that month, and it seemed probable that this new distribution of tonus in the flexors and extensors of the knee was a result of stretching the former and shortening the latter constantly for such a long time. It was a most desirable change, since it enabled him to walk. On the other hand, his case was unusual in that the knee flexors had originally shown a degree of hypertonus much more commonly found in the knee extensors and in the flexors of the peripheral joints of the upper limb. It was thought that if the same change could be produced in the muscles of the upper limb by similar means a useful therapeutic measure might be established. The considerable power which the flexors often possess is of little functional value when the joints cannot be voluntarily extended.

Material and Methods

Fourteen hemiplegic patients were selected and the response to stretch of 19 flexor muscle groups—18 in the upper limbs and 1 in the lower—was studied over a period of three years. The average duration of hemiplegia before beginning treatment was 18 months.

*This work is based on part of the material submitted for the M.D. examination, University of Glasgow.

Selection of Patients.—The following were the criteria used: the duration of the hemiplegia exceeded six months, its onset had been sudden, and was presumably of cerebrovascular origin; the musculature of the affected side presented constant tonic spasm; no improvement in active movement; and no lessening of tonus had been noted for a minimum period of four weeks. Some authorities (Lowman, 1948; Brain, 1955) have suggested that the period of spontaneous recovery of movement or decrease in hypertonus does not extend beyond the end of the third month after onset. Twitchell (1951), in his study of the natural course of hemiplegia, found that postural abnormality disappeared within 43 to 60 days in recovering cases. However, to avoid error with more certainty, six months was selected as signalling the end of natural improvement.

Controls.—The changes in the stretched flexor muscle group and in its shortened antagonist group were compared with those in the corresponding (untreated) groups controlling a neighbouring joint.

Treatment.—In each patient one or more flexor muscle groups, habitually held in a state of contraction by tonic spasm, were subjected to stretch by keeping the appropriate joint extended in a splint. This was maintained for a long period, usually about three months, during which time the splint was removed only long enough to wash the part twice each day. The patients were encouraged to move the joint actively during these free periods. Once flexion spasm had been abolished and an increased range of active extension established for at least a month the appliance was worn for progressively shorter daily periods and finally discarded. No other form of treatment was prescribed while the muscles were being stretched or during the follow-up period.

Examination.—To provide reliable results an accurate clinical method of measuring change in the degree of tonus and change in the range and power of active movement was required. An attempt was made to elaborate an acceptable method. A standard examination procedure was used at each examination; factors known to influence tonus and contractility, such as temperature, attitudinal reflexes, flexion and extension synergies, were also standardized on each occasion. Space does not permit full documentation of the examination technique, but it is necessary to describe one of its parts in order to make clear the section of results dealing with the effect of stretch on hypertonus. One of the ways in which decrease in flexor muscle tonus made itself evident was that the arc of passive movement from the position of full flexion towards the position of extension during which no resistance could be felt was found to progressively increase. The difference between the length of this arc before stretch began and the length when it was stopped is recorded in the results. Commonly the amount of this increase was such that the joint could be fully extended without resistance.

Results

The change in flexor tonus, measured by the change in range of unresisted passive extension movement at the end of the period of stretch, is shown in the Table (A 1). The spontaneous change in tonus occurring in the control flexor group, also measured at the end of that period, is also shown (A 2). As tonus in the stretched flexor group became reduced to normal the

Analysis of Results

Case No.	Age and Sex	Total Period of Stretch (Weeks)	Treated Group		Control Group	
			A 1 Increased Range of Normal Tone	B 1 Increased Range of Active Movement	A 2 Change in Range of Normal Tone	B 2 Change in Range of Active Movement
1	65 M	{ 36 22	Wrist 75° Elbow 40°	75° 40°	Fingers 10°	0°
2	28 M	{ 25 13	Wrist 85° Fingers 60°	85° 60°	Elbow -15°	-10°
3	38 F	18	Wrist 55°	50°	0°	5°
4	64 M	18	Fingers 70°	60°	Wrist 10°	10°
5	52 F	29	Elbow 70°	60°	0°	0°
6	13 F	{ 19 19	Wrist 65° Fingers 60°	60° 10°	Elbow 15°	5°
7	72 M	16	Wrist 60°	65°	.. -10°	-10°
8	62 F	{ 21 21	30° Fingers 70°	30° 10°	.. 10°	15°
9	51 F	{ 23 7	Wrist 35° Fingers 65°	30° 10°	.. 0°	-5°
10	75 F	14	Wrist 35°	40°	.. 10°	10°
11	47 M	34	Knee 55°	60°	Ankle 15°	15°
12	62 F	10	Wrist 55°	75°	Elbow 0°	0°
13	70 F	19	45°	10°	0°	0°
14	82 F	13	Elbow 50°	45°	Wrist -10°	-5°
Average		19.8	57°	46°	2.5°	2°

range of voluntary extension usually increased; the amount of this is shown (B 1), and the corresponding change in the control extensor group is given (B 2).

It is clear from the Table that in every case the change in the treated muscle groups is much greater than in the controls. Perhaps the most interesting feature of the study is that the first six patients (group 1) retained normal tonus in the treated muscle group, and also voluntary extension movement, until the time of writing. That is, for an average period of 58 weeks after stretch was stopped and complete freedom of the part permitted. It appears, therefore, that "permanent" abolition of hypertonus may be obtainable. The conditions favouring this lasting reduction in tone are suggested by comparing these cases with four patients (Cases 7-10; group 2) who have reverted to their original state in a similar time. (The remaining patients (Cases 11-14) have died from various causes; their progress prior to death is commented upon later.)

The average period of constant stretch for group 1 was 13 weeks against 8 weeks for group 2; the corresponding periods of intermittent stretch were 12 and 8 weeks. The degree of hypertonus presenting before treatment also appears to be important. In group 1 the average intensity was moderate, whereas in group 2 it was marked. In retrospect, it seems clear that the muscles of group 2 should have been stretched for even longer than those of group 1. Nevertheless, it was found that a lasting abatement of intense hypertonus could be achieved by very prolonged stretch; the wrist-joint of Case 1 was held flexed by intense spasm before treatment began. Finally, all the patients in group 1 made active use of their increased movement, whereas none of the patients in group 2 made any attempt to use their limbs. This may well have been an important factor.

Though the number of observations in this study was too small to formulate an accurate assessment of the lengths of the periods of stretch required to give lasting abolition of different degrees of hypertonus, the opinion was formed that for moderate spasm 12 weeks' constant and 8 weeks' intermittent stretch is required. For lesser and greater degrees the period should be adjusted accordingly.

As spasm in the flexor muscles of the knee or elbow joint abated it was usually possible to detect a heightened tonus in the extensors. The latter was seldom marked, and led to restriction of voluntary flexion in only one instance (Case 11). In the extensors of the wrist- and finger-joints no increase in tonus was ever detected.

The degree of tonus and the range of active movement varied very little in the control muscle groups. Clearly, demonstrable changes occasionally occurred, but were always temporary. No lasting change occurred outside the range of error (10-15 degrees) accepted in goniometric measurement.

In one of the four patients who died (Case 11) improvement was maintained from the time stretch was stopped until his sudden death from a second cerebrovascular accident six months later. The other three (Cases 12, 13, and 14) were showing a progressive loss of improvement at the time of death, three to four months after treatment stopped. This may, however, have been related to the general deterioration from various causes which they displayed. The response of the muscle groups in two other patients whose hemiplegia was of less than six months' duration has shown a similar pattern to those of the patients in group 1.

Discussion

Residual hemiplegia has become one of medicine's major problems, the magnitude of which may be judged from Rusk's (1954) estimate that there are one and a half million hemiplegic patients in the United States. In this country Elkington (1958) has called attention to the great and increasing incidence of cerebrovascular disease and its sequelae. Among the outstanding clinical features of the chronic stage are disabling paresis and hypertonus in the muscles of the affected side. Despite the functional improvement which may follow a course of rehabilitation these features tend to persist with little variation after the sixth month. There is clearly an urgent need for some means of effecting more complete recovery. Hopefully, there is reason to believe that the degree of paresis resulting from cerebrovascular lesions is not directly equated to the extent of pyramidal injury. In an extensive study of their relationship Lassek (1950) found no correlation whatsoever. Indeed, some hemiplegic patients presenting almost total loss of voluntary movement during life were found at necropsy to have an intact motor system. In such cases the cause of the motor deficit is not entirely understood. There is little doubt, however, that hypertonus plays a large part, the limbs being "splinted" by the muscle spasm (Berger and Schwartz, 1948). These workers have also shown that during abolition of spasm by adequate doses of spasmolytic drugs an increase in voluntary movement is obtainable. Unfortunately, there is no preparation available which can be continuously administered with safety in dosage which materially relieves spasm. While awaiting the advent of such a drug the method presented may have a useful place in treatment.

Most of the patients have achieved, and retained for long periods, a lessened flexor tonus and an increase in active extension which has improved function. Even when function was not greatly increased they were grateful to obtain a normal limb posture. The position of flexion almost invariably adopted by the peripheral joints of the upper limb is unsightly and is a source of great annoyance and frustration to most patients. An apparent disadvantage of the method is the long period

of immobilization required; but this is not of great importance, as the subject is not being deprived of a functional limb. Despite the tediousness of prolonged splinting no objections were raised to completing the prescribed periods of treatment; indeed, most patients appeared to welcome the method, perhaps encouraged by the positive approach to their disability.

In the series presented no skin abrasions resulted from wearing splints, nor was much discomfort complained of. It must, however, be emphasized that pain and skin damage will certainly occur unless an appliance of suitable design is devised, care taken in its manufacture, and the condition of the skin closely observed throughout treatment. The light-weight and well-padded polythene-polyurethane splint (Brennan, 1954, 1955, 1956) was found to be most satisfactory. Plaster-of-Paris was tried, but was discarded because of its great tendency to erode the skin. With all types of appliance oedema of the immobilized part sometimes occurred, but experience showed that it invariably disappeared rapidly when the period of constant stretch was completed.

Concerning the degree of active movement which may be expected to result from treatment, it was found that if the patient was able to grip fairly firmly then active extension at all joints of the upper limb could be gained. If the grip was absent or very feeble no useful recovery of active extension was obtained. When the anatomical admixture of fibres to both flexors and extensors occurring in the usual sites of brain damage is considered it is indeed logical to expect that either all will be destroyed or a proportion of fibres to both groups will be spared.

In recent years an increasing amount of research has been devoted to identifying the central mechanisms concerned in producing spastic states (Fulton and Kennard, 1934; Hines, 1936, 1937; Dusser de Barenne and McCulloch, 1938; Tower, 1940; Verhaart and Kennard, 1940; Lloyd, 1941; Mettler, 1943, 1944; McCulloch *et al.*, 1946; Bodian, 1946; Scarff and Pool, 1946; Magoun and Rhines, 1946, 1947; Niemer and Magoun, 1947; Snider *et al.*, 1947; Lindsley *et al.*, 1949). This work has shown that there are certain centres scattered widely throughout the central nervous system which subservise either facilitation or inhibition of muscle tone. They form two systems which oppose each other, and the sum of their effects is to maintain skeletal muscle in its normal state of perceptible tonus. In the vast majority of cases of hemiplegia the balance is upset in such a way that the facilitatory component is permitted to overact, producing hypertonus of the muscles on the affected side. Recent work with experimental animals has shown that the muscle spindle is the peripheral organ through which the facilitatory mechanisms produce and maintain rigidity (Hunt, 1951; Granit and Kaada, 1953; Eldred *et al.*, 1953). It seems probable that human hemiplegic hypertonus is effected in a similar way. The work of Sherrington (1894, 1900), Adrian and Zotterman (1926), Denny-Brown (1928), Fulton and Pi-Suñer (1928), Bronk (1929), Matthews (1931, 1933), and Hunt and Kuffler (1951a, 1951b) on the functions of the muscle spindle, and that of Merton (1951, 1953) on the servo-loop mechanism of voluntary muscle action, indicate how the extrapyramidal centres produce their effect upon both tone and voluntary movement.

It may be of some interest to speculate on the mechanism through which hypertonus was reduced by

the means described in the present study. The following theory is based upon the above-mentioned work. It is suggested that prolonged stretch of hypertonic muscle renders the sensory parts of its spindles irresponsive to stimulation at any length shorter than that which obtains when the muscle is held lengthened in the splint. Such a change would cause loss of response even though the central influences were unaffected. Alternatively, a reflex inhibitory cord mechanism might be involved (Hunt, 1951), but a certain constant clinical and electromyographic observation favours the former view.

If a flexor muscle group was held extended to a lesser degree than was possible by further lengthening, the reflex response to stretch was lost only up to the length at which the muscle was held in the appliance and further stretch produced a vigorous response. For example, where a wrist-joint was habitually held in postural flexion by tonic spasm, the splint was designed to keep it extended to only 30 degrees, the functional position, though extension to perhaps 70 degrees could be obtained by further pulling. After a sufficient period of stretch the joint could be passively flexed and extended again to 30 degrees without opposition, but at that point resistance became evident in the form of a sharp reflex contraction. Further extension required as much force as was originally needed throughout the whole range. This clinical finding was confirmed electromyographically; no response was evoked by passive extension to 30 degrees, but a burst of motor unit potentials was elicited by further stretch. It seems unlikely that if the change were in the neural mechanisms of the cord, or at a higher level, the response would be graded in such a manner.

This theory appears to receive support from an observation recorded by Denny-Brown and Liddell (1927). During preparation of chronic spinal dogs for their work on the stretch reflex they noted that hypertonus, originally marked in both the knee flexors and extensors, gradually became very much less in the latter while remaining unaltered in the former. They suggested that the stretch organs in the extensors were impaired by "chronic stretch" of those muscles, since all the preparations maintained an acute flexion of the knee as their ordinary resting posture during a post-operative period of some two months. It should, however, be noted that different species and different lesions in the central nervous system are being compared.

In conclusion it may be worth mentioning that patients with other diseases of the central nervous system, including cerebral palsy, disseminated sclerosis, and tuberculous meningitis were also treated. The number of cases available was insufficient to make up controlled series, but the results obtained suggest that both tonic and clonic muscle spasm associated with such conditions may be relieved by judicious periods of stretch.

Summary

The results of a controlled trial are presented in support of the thesis that the tonic muscle spasm shown by certain flexor muscle groups in patients with residual hemiplegia can be abolished by submitting the muscles to a long period of stretch. This was effected by keeping the appropriate joints, originally held flexed by spasm, extended in splints.

The response of 19 flexor muscle groups was studied over a period of three years. Each was constantly stretched for an average period of three months and for diminishing daily periods during the succeeding two

months. Control was exercised by observing any spontaneous change in the neighbouring unstretched groups in each patient. Hypertonus was abolished in all the treated flexor groups. Voluntary flexion was not impaired except in one case. The antagonist muscles achieved an increased power and range of movement in most cases. No lasting spontaneous change occurred in any of the control muscle groups.

Ten patients still survive. Of these, six have retained the above features in all of nine stretched muscle groups and their antagonists during an average period of 58 weeks since stretch was stopped. Six muscle groups in four patients have reverted to their original state in a similar time. The factors which may be responsible for this variable response are suggested.

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CONDITION OF TESTICLE AFTER DIVISION OF CORD IN TREATMENT OF HERNIA

BY

YESHWANT G. BODHE, F.R.C.S.Ed., F.R.F.P.S.
Honorary Surgeon, Sassoon Hospital, Poona, India

In large, indirect, long-standing hernias, in sliding hernias, and in frequently recurrent hernias orchidectomy has been recommended (Koontz, 1956; Aird, 1957). Dodd (1951) advised orchidectomy in men over the age of 70 in certain cases. Some of the patients who have undergone repair with no relief agree to the removal of the testis, though most of them are not willing to part with the organ. When the objections for removal of the testis were taken into consideration division of the cord at the internal ring without removal of the testis was contemplated. This technique, it was believed, would correct a defect inherent in all the standard primary operations for inguinal hernia and would give the same benefits of structural repair as could be expected after orchidectomy. The defect is due to the necessity for leaving an opening in the repaired tissue to allow a space for emergence of the spermatic cord.

Twenty-seven patients over 35 years of age were operated upon for inguinal hernia with the present technique. The youngest was 38 and the oldest 72, and the first case was operated on in September, 1952. Of these 27 hernias, 18 were on the right side and 9 on the left. Case 19 was direct hernia. Case 5 was operated on for recurrent hernia. No case of strangulated hernia was treated with this method.

Operative Technique

It is not proposed to give details of a standard procedure. The usual incision was made and the hernial sac exposed, separated, and excised at the internal abdominal ring. The cremasteric and the other areolar and adipose tissue were thoroughly cleaned out of the inguinal canal. At the internal ring the vas was ligated and cut, and the rest of the cord structures were transfixed and doubly ligated with linen or thread and cut. The portion in the canal was excised and the distal portion treated similarly. The proximal part of the cord stump was pushed back and the internal ring closed. It is imperative that the testis and the rest of the cord are not disturbed. The transversalis fascia was strengthened by reduplication or tautening the fascia by suturing it to the inguinal ligament with non-absorbable sutures. No tension was put on it, or it would give way and the original purpose of strengthening the area would be lost. The musculo-tendinous part of the conjoint tendon was sutured to the inguinal ligament only if it could be easily brought down and stitched without tension: if the arching is pronounced it cannot be brought down and sutured. Particular attention was paid in reinforcing the medial part of the canal. The external oblique should be sutured preferably with non-absorbable material, though in the present series catgut was used. The external ring was also closed, leaving the cord outside. Gentle handling of the tissues, great care in haemostasis, and rigid asepsis need not be emphasized to any surgeon, as a haematoma and infection are the major causes of failure and the viability of the testis remains in jeopardy.