PATHOLOGICAL PHYSIOLOGY AND GENERAL PATHOLOGY

CUTANEOUS STIMULI AND THEIR RELATION TO SPINAL REFLEXES IN THE DOG

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The problem of the restoration of function in a patient with a damaged or several spinal cord is one of the most difficult in the whole of neurology. In cases in which the cord has not been completely interrupted, a great deal of work has been done on remedial treatment, including passive and active exercises, massage, and baths [2, 3, 5, 7-9, 11, and others].

L. Guttmann [10] has claimed that even in patients with complete division of the cord, considerable compensation of function, and particularly of motor function, can be attained by special exercises. He attaches considerable importance to developing hypertrophy of the muscles of the upper part of the trunk, chiefly many of the back muscles. C. Long and E. Lawton [12] have described the muscular reorganization required for this purpose. By getting the patients to carry out exercises while in the vertical position, V. M. Ugryumov [6] and M. M. Krugly [1] obtained good results in cases of damage and even of interruption of the spinal cord. However, in spite of many attempts, the problem of the restoration of motor function in patients paralyzed as a result of spinal damage, has not yet passed beyond the experimental stage.

The present work reports results bearing on the part played by cutaneous stimuli in maintaining reflex activity in the distal part of the spinal cord in dogs after it had been completely divided, and the results may be relevant to the development of therapeutic methods.

METHOD AND RESULTS

In eight young adult dogs, the spinal cord was sectioned between the VI and VII thoracic vertebrae, and the animals were kept under observation for many years. They were divided into three groups. The first consisted of two dogs to whom no special cutaneous stimuli were applied, the second of two dogs in whom cutaneous stimulation was started 2 months after the operation, and the third of four dogs to whom stimulation was applied 2 weeks after the operation.

The cutaneous stimulation consisted of systematic use of massage, and also of scratching and pressure on certain of the paralyzed parts so as to elicit various spinal reflexes. In many cases, the mechanical stimulation was combined with electrical excitation applied through the skin of the foot. The stimulus was always suprathreshold, and caused a local spinal reflex. Three dogs of the last group were given massage and passive exercises daily. The living conditions and quarters were the same for all animals.

The reflexes studied were the extensor thrust, knee jerk, and flexor, scratch, and stepping reflexes; atypical motor reactions were also stimulated by stimulating fields outside those normally associated with a particular reflex. Such reactions included movement of the paw in response to electrical stimulation of the skin of the tail, tail movements evoked by electrical stimulation of the skin of the foot, etc. [4]. In all the spinal dogs, shortly after the operation and before the application of cutaneous stimulation, the flexor and knee jerk reflexes were weak; no atypical motor reactions were observed (Fig. 1).

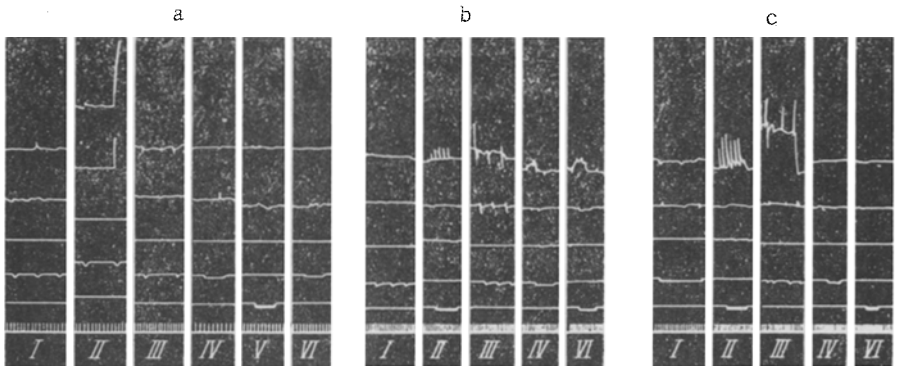

Fig. 1. Motor reflexes in spinal dogs 10 days after operation (before cutaneous stimulation). a) dogs from Group 1; b) dogs from Group 2; c) dogs from Group 3; I) extensor thrust; II) flexor reflex; III) knee jerk; IV, V) scratch reflex; VI) stepping reflex. Curves, from above downwards: movement of right foot; movement of left foot; tail movement; stimulus marker; time (1 second).

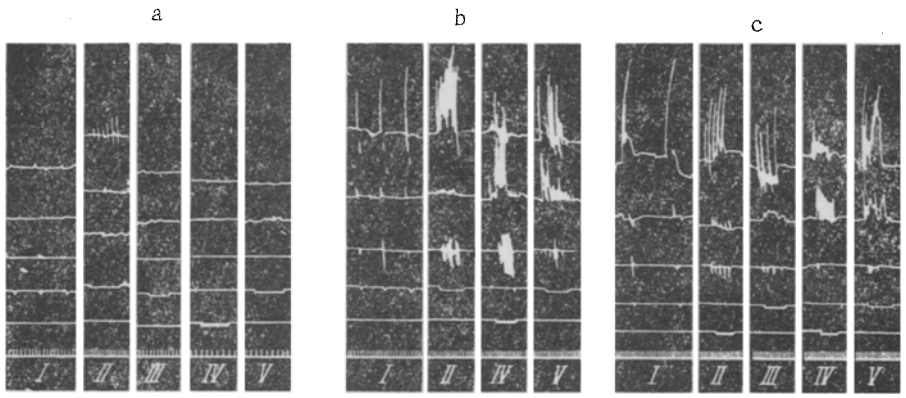

Fig. 2. Reflexes in spinal dogs with and without cutaneous stimulation. I) extensor; II) flexor reflex; III and IV) scratching reflex; V) stepping reflex. Other indications as in Fig. 1.

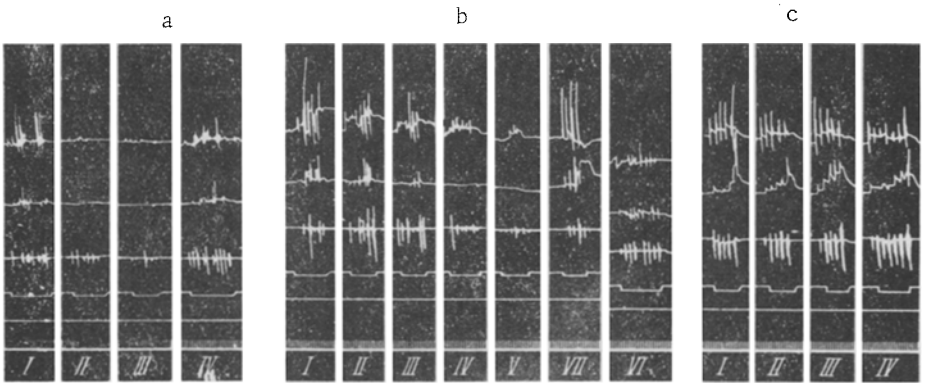

Fig. 3. Degree of stability of the atypical reaction in dogs of different groups. I) V) response to rhythmical stimulation of skin of tail; IVa and VI) response after a 10-minute rest; VII) response to stimulation of a second skin area in tail. Other indications as in Fig. 1.

In dogs of Group 1, (no special stimulation), there was some slight increase of the reflexes 1-2 months after the operation; subsequently they again became weaker, and after 6-7 months were at the original level (Fig. 2,a).

One year after the operation, just as before, only very limited reflexes could be evoked. Besides the flexor and knee jerk reflexes, in one a weak extensor thrust was developed, and in another the scratch reflex was present. In these animals there was considerable atrophy of the muscles of the hind limbs, and there was a deterioration of the joints. The hind limbs took very little part in walking, and usually dragged behind.

After 6-7 months, dogs of Group 2 who were given stimulation after 2 months, as a rule developed numerous well-marked but somewhat variable reflexes as well as an atypical tail reaction (Fig. 2, b). The condition of their hind limbs and method of movement was somewhat better than in those of the first group: although they crawled, the hing legs did not always drag, but took an active part in the movement.

The effect of cutaneous stimulation,begun immediately after the operation,was still more striking in the animals of the third group: after only 3 weeks from the time of the operation, good spinal reflexes developed, and even the atypical reaction of the paws in response to tail stimulation occurred (Fig. 2, c). Subsequently they moved better than dogs of the other two groups, because some of them developed a good extensor tone; they were able to stand, using their hind legs as a support, and even take a few steps without falling.

In order to obtain more detailed information about the functional condition of the caudal end of the cord as affecting the libility of nervous processes, we carried out tests to find whether the movement of the paw in response to tail stimulation occurred. To evoke this reaction, single shocks were applied simultaneously to the end of the tail and to the skin of the foot. The duration of each pulse was 100 msec, and the interval between them 2 seconds. A stimulus strength of 1.2-1.5 times threshold was chosen, and this caused a weak local reaction of tail and foot. The experiment was continued, and from 100 to 500 paired stimuli were applied. Dogs in the first group were first given the stimuli one year after the operation, the second group after two years, and the third group after 2 weeks. Before giving this treatment, none of the animals showed the atypical reaction.

The results obtained in group 1 were different from those in groups 2 and 3. Thus, in 4 animals of group 3, the atypical reaction of the paw appeared in the first experiment, although none of the animals had been giving massage or exercises. After a few repetitions, the reaction became strong and stable. Similar results were obtained in group 2. Thus, one animal was given 500 and another 600 stimuli in the second experiment, after which the atypical paw reaction was developed. However, at first the reaction was not stable, and did not become so until after the application of 3000 stimuli in one animal, and 5000 in the other; after this, it was maintained even after a 3-month interval.

In the first group, the atypical reaction of the foot to tail stimulation also appeared, although it was necessary to apply more stimuli than in group 2. However, the subsequent application of stimuli did not reinforce the reaction, and, on the contrary, it disappeared and did not return later, in spite of the fact that in 16-20 experiments the animal received 5000 double stimuli. Very little change in the other reflexes occurred through application of these stimuli. In one animal it was sometimes possible to induce an extensor thrust as well as the weak flexor reflex and knee jerk, and in another the scratching reflex could be evoked.

After carrying out these experiments on the dogs in group 1, a course of massage and passive exercise lasting almost 4 months was given, but the atypical reaction never appeared. There was scarcely any improvement either in the extensor thrust, scratching or stepping reflexes, despite a marked improvement in the condition of the muscles and joints of the hind limbs. Thus, cutaneous stimulation applied 1-1 1/2 years after the operation produces no essential change in the caudal section of the divided cord.

Of the other dogs, experiments with systematic massage, passive exercises, and electrical stimulation showed that quite early (10-14 days after the operation) the reflex activity of the caudal portion of the spinal cord returned rapidly. It appeared that systematic training undertaken shortly after the operation and designed to bombard the cord with afferent impulses, prevents the caudal portion from dystrophy and from the secondary effects resulting from it.

To test this hypothesis, we carried out experiments in which the nervous processes in the caudal portion were exercised to exhaustion. The experiments were performed as follows. During the period of active reflex activity, a voltage of 1.5 times threshold was applied to the skin, and the induced response of tail and paw was

recorded. The stimuli were given in groups at 1-minute intervals until the response began to fall off. The stimulation was then stopped, and renewed after a 10-minute interval. In the dogs of group 1, the atypical reaction ceased, even in the second group, the tail reaction was weakened, while in the case of the third group it almost disappeared. After a 10 minute interval, both reactions returned (Fig. 3,a).

In dogs of group 2, repetitive stimulation also caused an exhaustion of the atypical reaction as well as some weakening of the tail response, but for the latter it was necessary to repeat the stimulation 5-6 times. A control experiment to show that there was no fatigue in the muscle when the response failed was to stimulate another portion of the skin of the tail, which induced a well-marked reflex response (Fig. 3, b). It was not possible to observe any weakening of the reflexes in dogs of group 3: they were stable and well developed (Fig. 3, c). Consequently, the inability of dogs not receiving special stimulation to develop reflexes depends to some extent on the fact that such reflexes are easily exhausted.

The experiments demonstrated a functional difference between the caudal ends of the cords of stimulated and unstimulated animals. In the one case, it was possible to elicit spinal reflexes and even to develop new ones; in the second case, dystrophic processes resulting from inactivity caused almost complete loss of reflexes, which in turn affected the condition of the muscles and joints as well as the animal's movements.

The time elapsing between operation and treatment was of the greatest importance. When the time was short, the reflexes were rapidly activated, developing as the spinal shock wore off and remaining active for a long time. It appeared that having been freed from the influence of the higher centers, the spinal cord did not lose the ability to develop rapidly various kinds of reflexes, and that this ability, which was maintained by special stimulation, was retained and even showed some further development.

SUMMARY

Observations were made on 8 adult dogs in which the spinal cord was divided between the VI and VII thoracic vertebrae. Massage, scratching, and electrical stimulation were used to prevent dystrophy in the caudal portion of the cord. Two dogs were not stimulated, in two treatment was started after 2 months, while in the remainder the special stimulation treatment was started 2 weeks after the operation.

The activity and stability of various spinal cord reflexes and the ability to form atypical reactions served as the indices of the functional condition of the distal portion. The results of the experiments showed that the stimulation, especially when begun soon after the operation, was effective in arousing various spinal cord reflexes, even to the extent of elaborating new ones.

When no special stimulation was given, after only a few months, there was an almost complete loss of reflexes with inevitable deterioration of the condition of the muscles and joints and of locomotion.

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