THE NATURE OF SPINAL SHOCK

COMMUNICATION III. THE STATE OF THE AFFERENT NEURONES

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According to our results, spinal shock develops as a consequence of lack of tone in motoneurones which have lost their ability to become excited as a consequence of the rapid separation of the spinal nervous centers from the usual supraspinal tonic impulses. During this atonic period, the neurones are in a condition of anelectrotonus or hyperpolarization, and all the agents such as potassium chloride, eserine, proserine, and strong, maintained stimulation, which act parabiotically, prevent this lack of motoneurone tone from developing, and so oppose the development of spinal shock [3, 4 and 5]. However, the alternative view has been put forward [1, 2] that spinal shock represents a protective inhibition developing in the sensory part of reflex arcs as a result of their traumatic excessive stimulation. This protective inhibition passes through parabiotic phases.

The first set of experiments reported here was devoted to comparing the duration of the traumatic impulses in the pathways of the spinal cord and in the motoneurone after chordotomy. The second set of experiments was designed to determine the functional condition of the afferent section of the reflex arc during spinal shock.

METHOD

The experiments were carried out on frogs (Rana chensinensis) which were maintained in fixed position on a special stand. A two-channel cathode ray oscillograph was used to record the impulses from the posterior and lateral columns, in the central ends of the cut dorsal roots, and, in some experiments, in the muscles also. In all cases bipolar electrodes were used. The usual platinum electrodes were employed to measure the duration of the impulses in the nerve roots. In most experiments the uninsulated portion of the electrodes was 30 μ in diameter, and that of the insulated part 50μ. They were inserted into the columns of the spinal cord, dorsal roots, or muscles by a micromanipulator.

RESULTS

The first set of experiments enabled the duration of the traumatic impulses in the dorsal and lateral columns and the duration of the excitation in the ventral roots and semitendinosus muscle to be determined (Table 1).

The traumatic impulses passing along the posterior and lateral columns continued for approximately the same time, so that both these quantities can be considered together. For the same reason, the durations of the excitation recorded in the anterior roots and in the muscle (Table 2) can also be combined.

Tables 1 and 2 show that the length of time for which impulses flow in the axons of the posterior and lateral columns after chordotomy is very short, and has an average value of 0.88 seconds, varying between 0.15 and 2.7 seconds. On average, the discharge of the motoneurones lasts 6 times longer. This longer duration of 1.5-12-5 seconds is due to the closed circulation of impulses passing from the proprioceptors by the direct and indirect routes through internuncials to form segmental arcs, so causing a delay in the discharges in the cord. These features are illustrated by the oscillogram shown in Fig. 1.

TABLE 1

Duration of Traumatic Impulses in Chordotomy (in seconds)

Site from which traumatic impulses were recorded	Number of experiments	Time for which impulses occurred		
		minimum	maximum	average
Posterior columns	11	0,15	2.7	0,79
Lateral "	4	0,4	2.0	1,1
Ventral roots	15	1,55	10,0	5,33
Semitendinosus muscle	23	1,5	12,5	5,7

It was not possible to correlate the duration of the traumatic discharge in the cord or the excitation of the motoneurones with different functional conditions resulting from chordotomy (spinal shock, unchanged condition of reflexes, or exaltation of spinal reflexes) (Table 3).

The discharge in the motoneurones lasts for 5.5 seconds in spinal shock, but when chordotomy is followed by the condition of exaltation, it continues on average for 7 seconds. Therefore, these results may indicate that the more prolonged and greater degree of excitation of the motoneurones does not help, but rather hinders the development of spinal shock.

TABLE 2

Duration of Traumatic Discharge Caused by Chordotomy (in seconds)

Site from which traumatic impulses were recorded	Number of experiments	Time for which impulses occurred		
		minimum	maximum	average
A. Axons of the lateral and of the posterior columns.....	15	0,15	2,7	0,88
B. Anterior roots and muscle....	38	1,5	12,5	5,56

In the second set of experiments, we recorded afferent touch impulses induced by stimulation of the ventrolateral surface of the left foot of the frog by an automatic touch stimulator using a soft brush. The left anterior nerve roots were sectioned in order to exclude proprioceptor impulses. In 20 experiments, impulses from cutaneous receptors were picked up by electrodes inserted into the left ninth dorsal root ganglion close to its origin from the cord, while in 4 experiments these impulses were led off from the dorsal column. On the right side, where all the roots remained intact, a flexor reflex was was induced by stimulating the foot with a coarser brush. The contraction of the biceps femoris muscle was made electrically.

All 24 experiments showed that spinal cord section has no effect on the functional condition of the afferent link of the reflex arc. Whether the chordotomy resulted in spinal shock, as it did in 14 experiments, or whether the reflex excitability of the spinal cord was raised, as in 2 experiments, or whether the excitability was unchanged, the discharge from the cutaneous receptors remained unaltered both in the dorsal root ganglia and in the dorsal columns. The results are illustrated by the oscillograms from two experiments (Figs. 2 and 3).

The condition of the afferent pathways after chordotomy can be determined only by using a completely standardized method of stimulating the receptors. In our experiments, it was essential to exclude impulses from the proprioceptors, because the changed condition of the muscles resulting from chordotomy inevitably affected the sum total of the impulses in the dorsal roots and columns. Therefore, before the experiment was started, in frogs, the VIII-XI anterior roots on the left side were cut, and the electrode inserted into a position in the IX posterior root or column, such that touching the left foot produced a clearly shown volley of impulses.

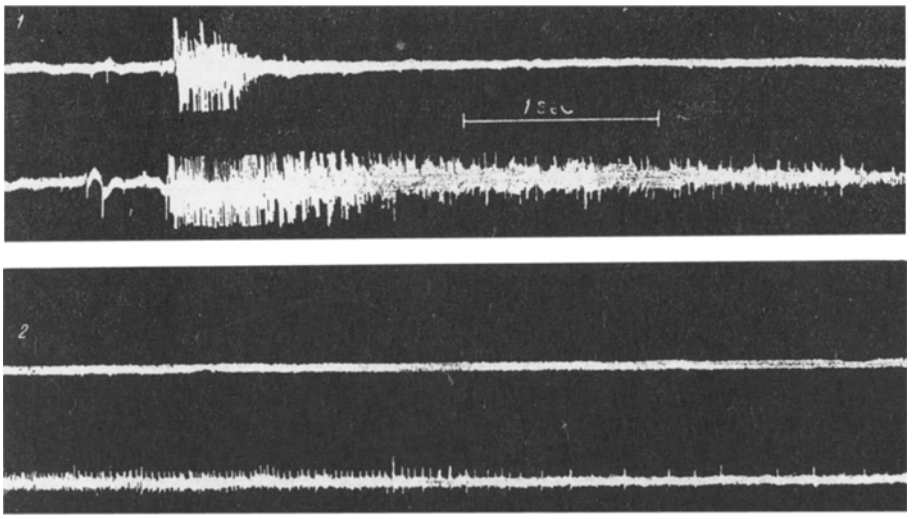

Fig. 1. Duration of discharge following chordotomy. Experiment No. 25. Curves, above downwards: nerve impulses in posterior column of spinal cord, same in central end of right ventral root. 1) Nerve impulses during chordotomy ; 2) continuation of the upper oscillogram.

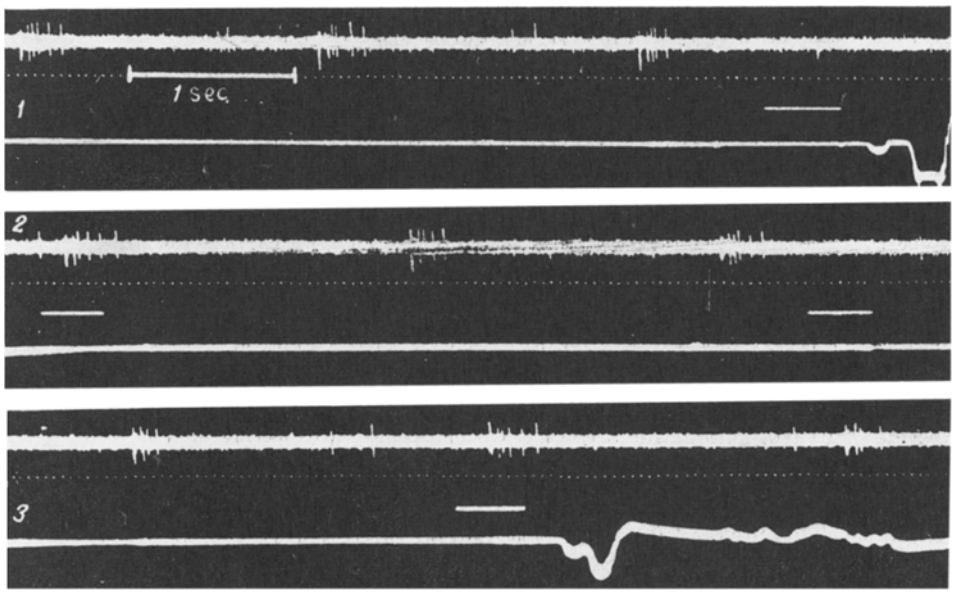

Fig. 2. Recording of afferent impulses in posterior root during chordotomy. Experiment No. 67. Curves, from above downwards: impulses in left posterior root on stimulating skin of foot automatically with a touch stimulator, trace showing stimulus to right foot, electrical record of reflex contraction of right biceps femoris. 1) Initial condition, before chordotomy ; 2) immediately after chordotomy, no reflex, spinal shock ; 3) 4 minutes after chordotomy, reflex returns.

The touch stimulator was operated by a small wheel with three teeth. The three touch stimuli were not absolutely identical, but they were repeated in a consistent order. From Fig. 2, it can be seen that the duration of the volley in the posterior root, the grouping of the impulses, and even the number in a volley, as produced by the successive stimuli, are almost exactly the same in the three oscillograms taken before chordotomy, during spinal shock, and after the restoration of the reflexes. The recording of the right biceps femoris contraction shows the state of excitation of the spinal cord existing at the time the afferent volley was recorded.

TABLE 3

Comparison of the Duration (in seconds) of the Traumatic Discharge with the Functional Condition of the Spinal Cord after Chordotomy

Functional condition after chordotomy	Duration of discharge					
	spinal tracts			motoneurones		
	minimum	maximum	average	minimum	maximum	average
Spinal shock	0,15	1,4	0,6	1,5	9,9	5,5
No change	0,4	2,7	2,2	2,1	10,0	4,9
Exaltation	0,5	0,55	0,52	6,4	7,5	7,0

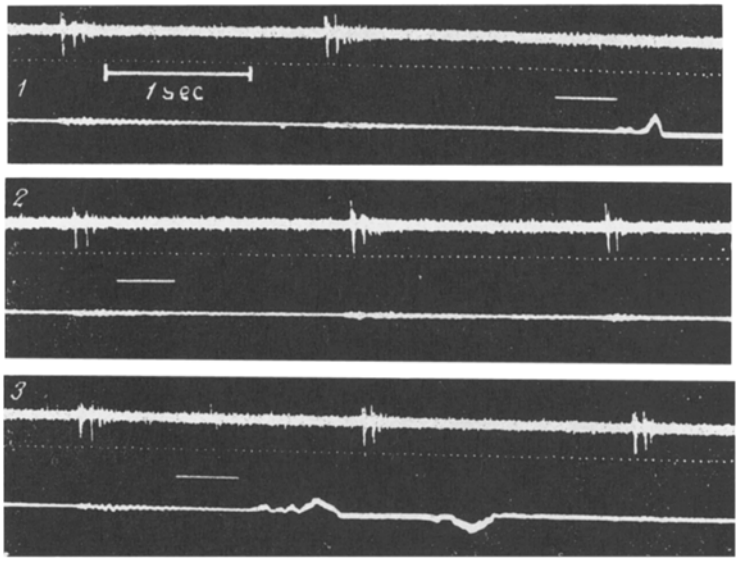

Fig. 3. Afferent impulses in posterior column of spinal cord in chordotomy. Experiment No. 71. Curves, from above downwards: nerve impulses in left dorsal column of cord on stimulating skin of foot automatically with a touch stimulator; other features as in Fig. 2. 1) Initial condition before chordotomy; 2) immediately after chordotomy, no reflexes, spinal shock; 3) 3 minutes after chordotomy, reflex returns.

Fig. 3 gives traces in which the afferent impulses were recorded from the posterior columns. In this case too, the impulses retain the same features when recorded during spinal shock, and they are not changed later when the spinal reflexes become restored.

Thus, our experiments give no support to the suggestion that spinal shock is the result of a protective inhibition developing in the sensory portion of reflex arcs due to traumatic over-stimulation.

SUMMARY

A study was made of the effect of chordotomy on voltages recorded from the posterior and lateral columns of the spinal cord, from the anterior and posterior nerve roots, and from certain muscles.

It was shown that section of the cord causes a discharge of impulses in the posterior and lateral columns which lasts on average for 0.88 second. The average period of excitation of the motoneurones is six times longer, and it is thought that this is due to the circulation of impulses in segmental reflex arcs. No connection was found

between the period for which the impulses were generated and the condition of the spinal reflexes obtained after the chordotomy. Spinal shock is not the result of prolonged stimulation. A study of the impulses generated by a standardized cutaneous stimulation showed that they remained unchanged in all parts of the afferent pathways of the cord.

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