AN EXPERIMENTAL ANALYSIS OF THE PHENOMENON OF SPINAL SHOCK

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In connection with our findings that the sensory links of the somatic reflex arc are mainly affected in spinal shock, and also with É. A. Asratyan's [1] data on the consequences of section of the posterior half of the spinal cord, the experimental investigation of the degree of involvement of the various links of the vegetative (especially vasomotor) reflex arcs in spinal shock is of great interest.

Total transverse section of the spinal cord not only modifies the activity of the skeletal musculature, but it also alters the activity of the vegetative functions. In 1859, Claude Bernard [7] showed that, after high section of the spinal cord, the circulation of the blood is affected, primarily by a sharp fall in the arterial pressure. A similar phenomenon was also observed by Bezold [6] in 1863. He showed that the rise in arterial pressure which is normally observed during stimulation of various nerves is absent after total section of the spinal cord. Ludwig and Trie [8] also found a fall in the arterial pressure after total section of the spinal cord and showed that the level of the blood pressure may be again raised by electrical stimulation of the cross section of the caudal segment of the divided spinal cord.

A fall in the arterial pressure after high section of the spinal cord was also found in experiments by many other workers [5, 1, 2, 4, 9] and also in our own experiments, carried out on a large number of adult dogs. The increase in pressure in response to stimulation of the peripheral end of the divided spinal cord, previously observed [8], indicated that the function of the efferent vasoconstrictor neurone was essentially unaffected and that, consequently, the fall in the arterial pressure after high section of the spinal cord is due to changes in the functional state of other links of the reflex arc.

The object of the present investigation was to carry further the study of the problem whether depression of the sensory part of the reflex arc is the main cause of the disturbance of the reflex activity of the vasomotor centers of the spinal cord.

METHOD

In order to elucidate this problem which we had set ourselves, a series of experiments was carried out in which the different columns of the caudal segment of the divided spinal cord were stimulated in as localized a manner as possible, and the ensuing changes in the arterial pressure were examined. Observations were made on twelve adult dogs. Total section of the spinal cord was performed under morphine-ether-chloroform anesthesia in ten dogs at the level of the first thoracic segment, and in two dogs at the level of the fourth cervical segment. After section, the anesthesia was terminated and the remainder of the experiment was undertaken without anesthesia. Division of the spinal cord at the level of the fourth cervical segment, and the whole of the subsequent experiment, were carried out with the aid of artificial respiration.

The different columns of the spinal cord were stimulated by immersible electrodes, the ends of which were coated with special electrically insulating lacquer, so that only a very small part of the surface of the electrodes remained uncovered, in direct contact with a given area of the spinal cord. The columns of the caudal segment of the divided spinal cord were stimulated by means of an induction current from a Dubois-Reymond coil or by means of a stimulator. Stimulation lasted 20 seconds with intervals of 4 minutes between stimulations (after many tests we came to the conclusion that this was the optimal duration of stimulation). In two dogs—Belyanka and Bobik—besides stimulating the various columns of the spinal cord, we also stimulated the sciatic nerve by means of specially made immersible electrodes. To prevent transfer of loops of current to the cranial end of the divided spinal cord, the latter was earthed and additionally an area of cord 1-1.5 cm long was resected to increase the gap between the cranial and caudal ends of the divided spinal cord.

RESULTS

At the moment of division of the spinal cord the arterial pressure rose sharply and stayed at a high level for approximately 3-4 seconds, after which it gradually (for 50-80 seconds) fell. After total section of the spinal cord the arterial pressure fell on the average by more than 50% of its initial level. Its usual value was 40/50 mm Hg. When the arterial pressure fell still lower, which happened after division of the spinal cord at the level of the fourth cervical segment and also when hemorrhage was profuse during exposure of the spinal cord, we gave intravenous injections of a mixture of 10% calcium chloride with 40% glucose solution (into the femoral vein). This measure was highly effective in every case. In the dog Zheltushka, for

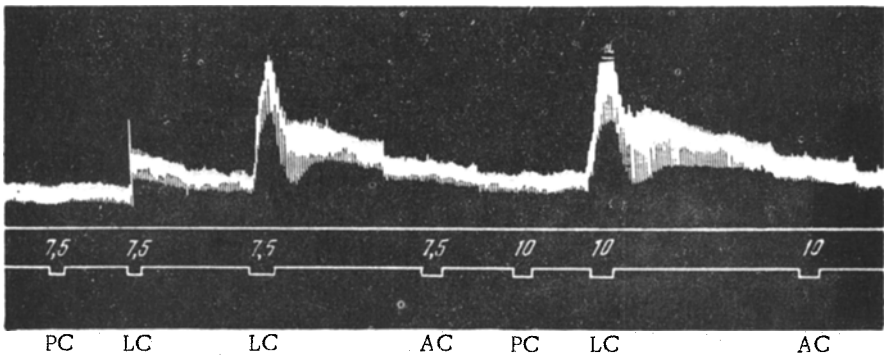

Fig. 1. Arterial pressure in the dog Bokser during stimulation of the anterior, posterior and lateral columns of the caudal end of the spinal cord, divided at the level of the first thoracic segment. Significance of the curves (from above down): arterial pressure; zero line; stimulation marker. The figures indicate the tension of the current (in volts), the letters—the area stimulated (L. C.—lateral columns, A. C.—anterior columns, P. C.—posterior columns). Intervals between stimulations 4 minutes.

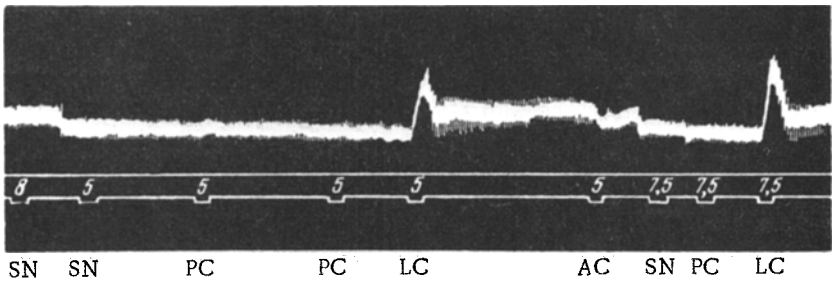

Fig. 2. Arterial pressure in the dog Belyanka during stimulation of the sciatic nerve and the anterior, posterior and lateral columns of the peripheral end of the divided spinal cord by means of an electric current. Legend as in Fig. 1. Intervals between stimulations 4 minutes. (SN—sciatic nerve).

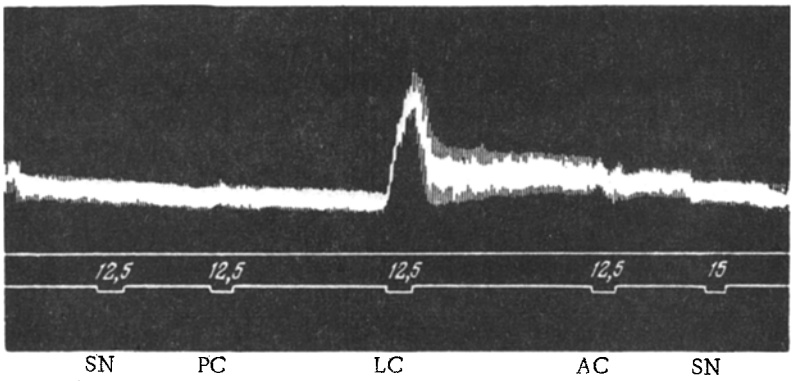

Fig. 3. Arterial pressure in the dog Bobik during stimulation of the sciatic nerve and of the anterior, posterior and lateral columns of the peripheral end of the divided spinal cord. Legend as in Fig. 1.

instance, as the result of profuse hemorrhage during exposure of the spinal canal the arterial pressure fell to 20/15 mm Hg even before division of the spinal cord, and it continued to fall. By means of two injections of calcium chloride with glucose (2 cm^3 of 10% calcium chloride and 8 cm^3 of 40% glucose on each occasion) we were able to raise the general level of arterial pressure to 80/60 mm.

The body temperature of the dogs fell to 34-36° after section of the spinal cord, and during acute experiments we therefore applied hot-water bottles to the dogs. After the animals had recovered from anesthesia and the arterial pressure had become stabilized at a definite level, stimulation was given to the different columns of the spinal cord.

Stimulation of the lateral columns of the spinal cord always elicited a quite strong and prolonged rise of the arterial pressure, which did not fall to its original value when the stimulation was discontinued. Stimulation of the anterior columns sometimes led to a slight increase in the arterial pressure, which rapidly fell to its initial level on discontinuing the stimulation, although occasionally the level of the arterial pressure remained unchanged. Stimulation of the posterior columns usually caused no change in the arterial pressure, and the changes if they did occur were extremely small and transient increases (Fig. 1).

In two dogs—Belyanka and Bobik—we stimulated the sciatic nerves in addition to the anterior, posterior and lateral columns of the caudal segment of the divided spinal cord. In the dog Belyanka the spinal cord was divided at the level of the fourth cervical segment. Division of the spinal cord and the subsequent experimental procedure were conducted with the aid of artificial respiration. In the dog Bobik the spinal cord was divided at the level of the first thoracic segment.

In all cases stimulation of the sciatic nerve caused no change in the arterial pressure either in the dog Belyanka or in the dog Bobik. Stimulation of the anterior and posterior columns also left the arterial pressure almost completely unchanged.

Stimulation of the lateral columns of the divided spinal cord caused a very considerable increase in the level of the arterial pressure in both dogs (Figs. 2 and 3).

In all our experiments in which the different columns of the divided spinal cord were stimulated in as localized a manner as possible, it was found that direct stimulation of the descending spinal tracts, connected with neurons situated in the lateral horns of the caudal end of the divided spinal cord, was always accompanied by a considerable rise in the level of the arterial pressure.

Stimulation of the sciatic nerve and of the posterior and anterior columns of the spinal cord, i.e., of pathways not connected with the above-named neurones, either caused no change whatsoever in the arterial pressure level, which was most often observed, or it led to a very slight increase in the pressure.

These facts may be explained by disturbances of the excitation level of the sensory links of the vasomotor reflex arc.

Our experimental results thus confirm the truth of the view developed by É. A. Asratyan, namely that in spinal shock it is mainly the sensory part of the reflex arc in which changes take place.

SUMMARY

Acute experiments were conducted on adult dogs with local stimulation of various tracts of divided spinal cord (caudal section). A considerable pressure rise always accompanied stimulation of the lateral columns of divided spinal cord. Stimulation of the sciatic nerve, posterior and anterior columns either had no effect whatsoever on the arterial blood pressure (which was observed more frequently) or its rise was insignificant. These facts may be explained by disturbed excitation of the sensory links in the vasomotor reflex arc.

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