THE EFFECT OF MECHANORECEPTORS OF THE URINARY BLADDER UPON THE STRIATED MUSCULATURE

Report I. The Effect of Mechanoreceptors of the Urinary Bladder on the Striated Musculature Taking Part in the Act of Micturition

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In previous reports [2, 3, 4] it was shown that impulsation in the afferent nerves of the urinary bladder gives rise to certain reflex changes in the tonus of its musculature and the musculature of the urethra, which differ during the filling of the urinary bladder and during its evacuation. It was established that this difference in the reactions is determined by a differing intensity in the afferent impulsation [1, 12]. A number of investigators, having studied the reflex changes during the act of micturition, also noted involvement of a definite group of skeletal muscles in this act.

Thus, D. Denny-Brown and E. Robertson [9], S. Muellner [13] et al., observed contraction of the abdominal muscles during the act of micturition. J. Evans [10] recorded inhibition of the efferent impulses in the nerves innervating the m. levator ani, m. bulbocavernosus, and the muscle of the external urethral sphincter. In addition, many investigators noted relaxation of the external sphincter, which is composed of striated muscle [7, 8, 9, 11, et al.].

In this work we report the results of the investigation, whose purpose was to study the reaction of the external sphincter and the oblique abdominal muscle during the filling of the urinary bladder and at the time of its evacuation.

EXPERIMENTAL METHOD

The experiments were carried out on cats, kept under urethan or nembutal narcosis. The narcotic was injected intravenously. In all, 33 experiments were set up. The action potential of the muscles was recorded by using a double-channeled cathode oscillograph with an amplifier; the monitored band of the latter was set at rectilinear, within the bounds of 10 to 500 cps. For the conduction of the action potentials of the muscles, we used needle-shaped silver electrodes. Stimulation of the mechanoreceptors in the urinary bladder was carried out by filling the bladder with air under a determined pressure. The latter was recorded on a smoked kymograph drum, on which a record was also made of respiratory movements.

EXPERIMENTAL RESULTS

During the time that the urinary bladder remained empty, we noted the background activity of the muscles of the external sphincter as well as the abdominal muscles (Fig. 1a; Fig. 2a). It was shown that with stimulation of the mechanoreceptors in the urinary bladder, the lowest threshold is observed for the reflex giving rise to alterations in the muscular activity of the external sphincter; in association with this, an increase occurs in the bioelectrical activity of these muscles, at the same time that the activity of the oblique muscles of the abdomen remains the same (see Fig. 1b). As has been shown earlier [2, 4], at this time the impulsation in the n. pudendus, innervating the urethra, becomes stronger, and the tonus of the latter increases.

A small increment in the strength of stimulation of the urinary bladder mechanoreceptors continued, as before, to cause an increase in the biopotentials of the muscles of the external sphincter, while the activity of the abdominal muscles was somewhat inhibited (see Fig. 1c). Further intensification of the stimulation gave rise to rhythmic changes in the bioelectric activity of the muscles of the external sphincter, analogous to the strengthening and weakening periods of efferent impulsation to the urethra via the n. pudendus; at this time the activity of the abdominal muscles continued to be inhibited (see Fig. 1d). Subsequent increase in the strength of stimulation caused inhibition of the activity

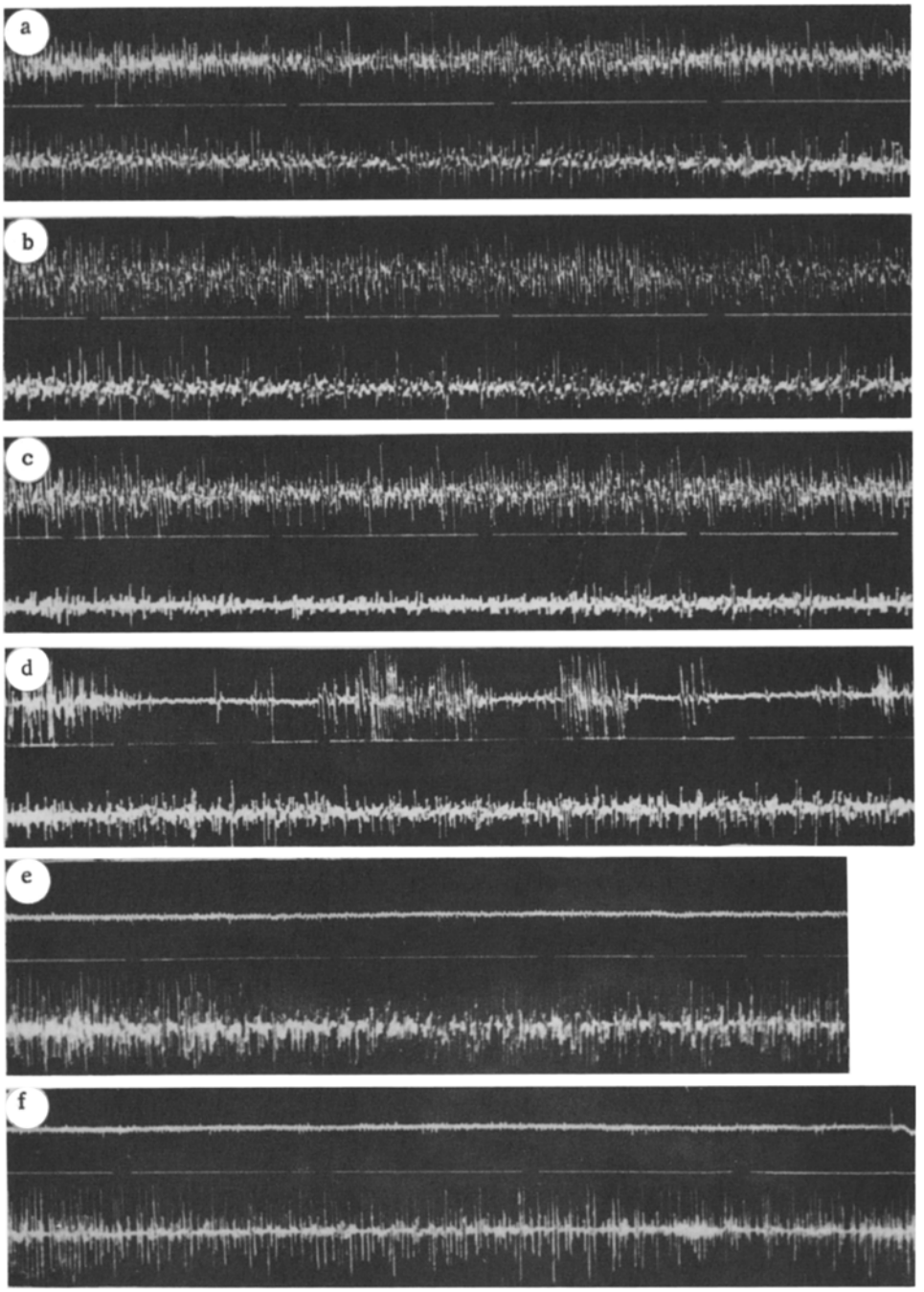

Fig. 1. Changes in the activity of the muscles in the external sphincter of the urethra and the oblique abdominal muscle with varying strengths of stimulation to the mechanoreceptors of the urinary bladder. a) Background activity of the muscles of the external sphincter and the oblique abdominal muscle with the urinary bladder empty; b) pressure in the urinary bladder: 8 mm of mercury, showing that the activity of the external sphincter is increased, and the pressure of the abdominal muscles is unchanged; c) pressure in the urinary bladder: 11 mm of mercury, showing an increase in the activity of the external sphincter and inhibition of the abdominal muscles; d) pressure in the urinary bladder: 18 mm of mercury, showing rhythmic activity of the external sphincter and inhibition of the activity of the abdominal muscles; e) pressure in the urinary bladder: 40 mm of mercury, showing inhibition of the activity of the external sphincter and strengthening of the abdominal muscles; f) pressure in the urinary bladder: 146 mm of mercury, showing inhibition of the activity of the external sphincter and strengthening of the abdominal muscles, but less than in Fig. 1e. Significance of the curves (from above downward): action potentials of the muscles of the external sphincter, time marks – 1 second, action potentials of the oblique abdominal muscle.

in the external sphincter. At this time inhibition of the action potentials in the n. pudendus, innervating the urethra, and relaxation of the urethra, were observed [2, 4]. Simultaneously with the deceleration of the activity in the external sphincter, the activity of the abdominal muscles increased (see Fig. 1e). Contraction became increasingly stronger with subsequent increase in the distension of the urinary bladder. However, extreme stimulation (elevation of the pressure in the urinary bladder to 150 mm of mercury or higher), on the other hand, caused smaller contractions of the abdominal muscles (see Fig. 1f) than stimulation of a more moderate strength. An effect such as this from extreme stimulation was observed in approximately half of the total number of trials; in the other trials, under these conditions, the result was an inhibition in the activity of the oblique abdominal muscles.

In several trials the background activity of the abdominal muscles presented itself as volleys of impulses, synchronous with the respiratory movements. In these trials, as well as in those described above, inhibition was noted in the activity of the abdominal muscles upon weak stimulation of the urinary bladder mechanoreceptors, and an increase in activity was observed in response to strong stimulation, while this increase was less marked with the application of extremely strong stimulation. The reactions of the oblique abdominal muscles often did not coincide with the reflex changes in the respiratory movements, which were inhibited in association with weak and moderate stimulation of the urinary bladder mechanoreceptors, and showed increased strength only with rather intense stimulation of the latter.

In the process of recording the bioelectric activity of the oblique abdominal muscles at their opposite ends (the distal end was placed in direct proximity to the urinary bladder, the proximal end was fastened to the ribs and removed from the urinary bladder for a certain distance), it was possible to observe that the reflex alterations initially appeared in the distal portion of the abdominal muscle and then, after 2-0.3 seconds, they arose in the proximal portion of the same muscle (see Fig. 2a, c). With stimulations of higher strength this difference in the latent periods became smaller or disappeared. Thus, at the strengths of stimulation which act under natural conditions, the reaction of the abdominal muscle begins at that portion of it which is located in the vicinity of the urinary bladder, and only subsequently does the reaction spread into the other portions

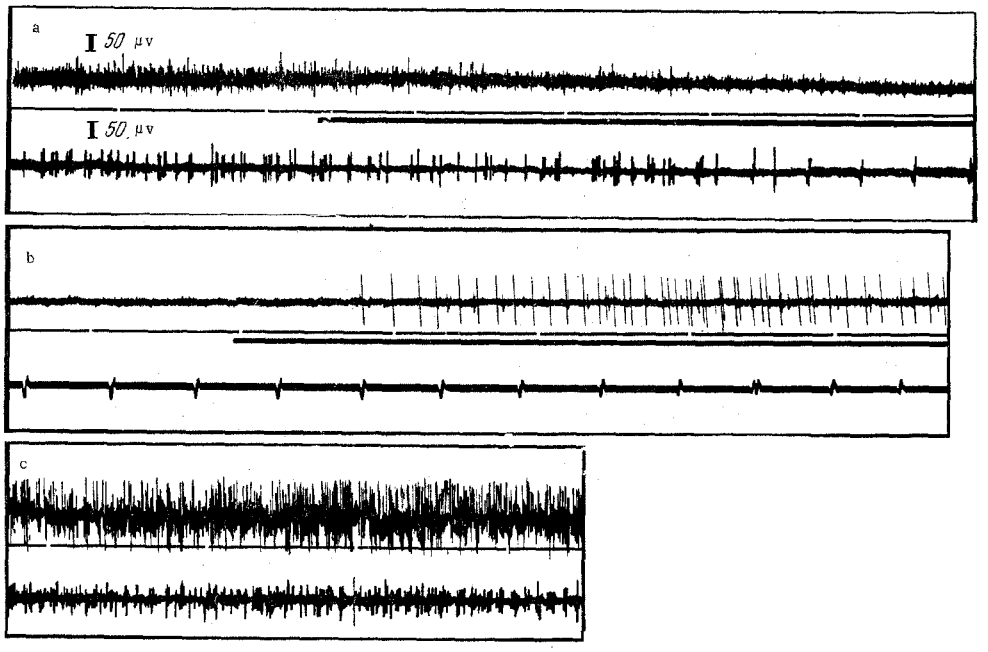

Fig. 2. Changes in the activity of the oblique abdominal muscle at different levels with stimulation of the urinary bladder mechanoreceptors. a) Pressure in the urinary bladder: 16 mm of mercury, showing inhibition of the activity of the oblique abdominal muscle in its distal portion with a latent period of 1 second, in its proximal portion with a latent period of 2.5 seconds; b) pressure in the urinary bladder: 24 mm of mercury, showing an increase in the activity of the oblique abdominal muscle in its distal portion with a latent period of 0.6 seconds, in its proximal portion with a latent period of 4.6 seconds; c) pressure in the urinary bladder: 33 mm of mercury, showing a differing degree of increase in the activity within the distal and proximal portions of the oblique abdominal muscle. Significance of the curves (from above downward): action potentials of the distal portion of the abdominal muscle, time marks – 1 second, stimulation record, action potentials of the proximal portion of the abdominal muscle.

of the muscle. In addition to the indicated difference in the latent periods for the two portions of the oblique abdominal muscle, it was also possible to note a difference in the strength of the reaction of these portions in response to the identical strength of stimulation to the urinary bladder mechanoreceptors. The reaction of the distal portion of the muscle was more intense than the response of the proximal portion (see Fig. 2c).

Thus, the picture described earlier [2, 4] of the reflex changes arising in the period during which the urinary bladder is filling with urine and is subsequently evacuated may be supplemented with the characteristics of the reaction of the striated musculature which takes part in these processes (Fig. 3). It has been established that, in the period when a contraction arises in the muscles of the external sphincter and a relaxation occurs in the muscles of the urinary bladder [4], a relaxation also begins in the abdominal muscles (the threshold of these reflexes is somewhat higher than for the first two). The latter, obviously, leads to a decrease in the intra-abdominal pressure, which engenders an increase in the storage capacity of the urinary bladder. Thus, the conjunction of reflexes in the smooth muscles of the urinary bladder, the striated muscles of the external sphincter, and the abdominal muscles, secures the reservoir function of the urinary bladder.

With an increase in the filling of the urinary bladder, there follows a relaxation of the external sphincter and a contraction of the muscles of the urinary bladder. In

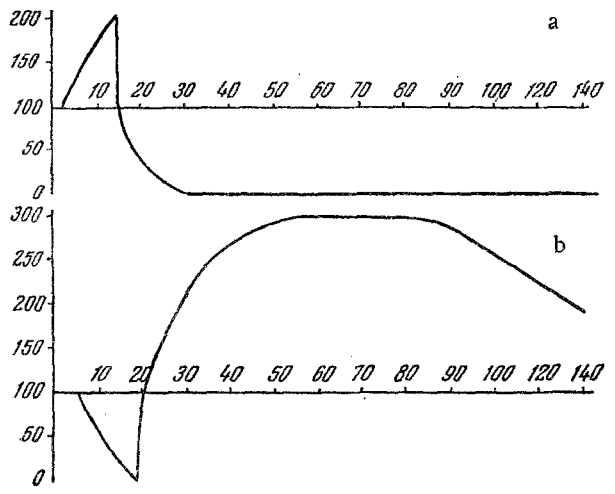

Fig. 3. The relation of the reflex alteration in the activity of the muscles in the external sphincter and the oblique abdominal muscle to the intensity of stimulation of the urinary bladder mechanoreceptors (schematically). On the abscissa – intensity of stimulation of the urinary bladder mechanoreceptors, in millimeters of mercury; on the ordinate – action potentials (a – external sphincter, b – oblique abdominal muscle) in percent of the original level, which was taken to be 100.

those instances wherein a simultaneous contraction of the muscles of the external sphincter and the urinary bladder is observed, the abdominal muscles either still remain relaxed or begin to contract. Contraction of the abdominal muscles becomes more intense when the external sphincter dilates. This reaction promotes the elevation of the pressure in the abdominal cavity and in the urinary bladder, i.e., the most rapid and complete evacuation of the bladder.

Comparing the material of the present report with the data published by us earlier on the reflexes arising from stimulation of the urinary bladder mechanoreceptors [2, 3, 4], we must above all, devote attention to the fact that the range of local or systemic [5, 6] reflexes for the given stimuli is not limited to reflex effects on internal organs, with their characteristic smooth musculature. The external sphincter of the urethra, although indeed consisting of striated muscle, cannot be regarded as skeletal muscle, but the oblique abdominal muscle incontrovertibly belongs to this category. The reflex reactions of these two striated muscles arise with rather low thresholds of stimulation, close to the threshold for the generation of afferent impulsation from the receptors of the urinary bladder, and they undergo changes in functional significance with stepwise intensification of the stimuli, i.e., with transition from a reservoir function for the urinary bladder to an evacuatory one. According to all these characteristics, the reflexes described in this report enter the "physiological system," arising in response to stimulation of the urinary bladder, and they must be included in the "systemic" category. This especially pertains to the reflexes of the external sphincter, appearing in this physiological system as the "most systemic," and, to a lesser degree, to the reflexes of the oblique abdominal muscle, arising from somewhat higher thresholds. The latter may be regarded as less local than the reactions of the renal vessels [3]. In conclusion, it should be noted that, with stimulation of the urinary bladder receptors, the reactions of many internal organs not directly related to urinary excretion must be characterized as much further interlinked than the reactions of the skeletal muscle entering into this physiological system.

SUMMARY

The reflex changes of the activity of striated muscles of external sphincter and oblique abdominal muscle were studied in acute experiments on cats. With low filling of the urinary bladder, the activity of external sphincter (contraction) and the inhibition of abdominal muscles activity (relaxation) becomes increased. This promotes the filling of the urinary bladder, i.e., the accomplishment of its function as a reservoir. With greater accumulation of liquid in the urinary bladder, the activity of the external sphincter is inhibited (it relaxes, and there is a rise of the ab-

dominal muscles' contraction activity), promoting evacuation of the urinary bladder.

LITERATURE CITED

1. N. A. Adamovich, Works of the I. P. Pavlov Inst. of Physiology [in Russian] (1954) Vol. 3, p. 490.
2. T. S. Lagutina, Byull. Éksp. Biol. Med. 44, 7, 3 (1957).*
3. T. S. Lagutina, Byull. Éksp. Biol. Med. 47, 1, 3 (1959).*
4. T. S. Lagutina, Fiziol. Zhur. SSSR 44, 214 (1960).
5. V. N. Chernigovskii, Uspekhi Sovrem. Biol. 23, 215 (1947).
6. V. N. Chernigovskii, Trudy Voenno-Morsk. Med. Akad. 17, 395 (Leningrad, 1949).
7. F. J. F. Barrington, Quart. J. Exper. Physiol. 8, 33 (1914).
8. F. J. F. Barrington, Brain 54, 177 (1931).
9. D. Denny-Brown and E. G. Robertson, Brain 56, 149 (1933).
10. J. P. Evans, J. Physiol. 86, 396 (1936).
11. M. J. E. Guyon, Compt. rend. Soc. biol., 712 (1900).
12. A. Iggo, J. Physiol. 128, 593 (1955).
13. S. R. Muellner, J. Urol. 65, 805 (1951).

*See English translation.