REFLEX RESPONSES OF THE URETHRAL SPHINCTER TO STIMULATION OF THE PUDENDAL AND PELVIC NERVES BY SINGLE PULSES

V. A. Kuz'menko

UDC 612.467.11-06:612.819.94

A study of bioelectrical responses of the urethral sphincter to stimulation of the central ends of the divided pudendal and pelvic nerves showed that the threshold amplitude of the stimulus and latent period of the response are higher to stimulation of the pelvic nerves than of the pudendal. With an increase in pressure in the bladder, the amplitude of the response to stimulation of both groups of nerves at first increases and then decreases.

Stimulation of the pudendal nerves is followed by a prolonged after-depression the depth of which depends on the amplitude of the stimulus. Stimulation of the pelvic nerves leads to polyphasic changes in excitability. In this case a phase of exhaltation is observed if the stimulus amplitude is high.

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If the strength of stimulation of mechanoreceptors in the distal part of the urethra [2] and urinary bladder [3] is increased, the bioelectrical activity of the urethral sphincter muscle at first increases and then decreases down to total inhibition. However, the shape of the curves describing the relationship between the amplitude of this activity and the strength of stimulation differs in the two cases. A particularly clear manifestation of this difference is that the increase in activity in response to stimulation of receptors of the distal part of the urethra is much greater than in response to stimulation of the bladder receptors.

For a more detailed analysis of the nervous mechanisms of sphincter reflexes, it is essential to know such important parameters of these reflexes as the thresholds of stimulation and maximal response, latent periods, and change in excitability of the nervous centers. To determine these parameters the method of electrical stimulation of the corresponding afferent pathways was used.

EXPERIMENTAL METHOD

Experiments were carried out on 30 fully grown cats anesthetized with urethane (1 g/kg). Stimuli from a two-channel stimulator were applied to the central ends of the divided branches of the pelvic nerve containing afferent fibers from the bladder, and of the pudendal nerve containing afferent fibers from the distal part of the urethra and the perineal skin. The distance between the stimulating electrodes was 4 mm and the stimulus duration 0.2 msec; the intensity was above threshold. Potentials of the sphincter muscles were detected by needle electrodes and recorded on a CRO.

EXPERIMENTAL RESULTS AND DISCUSSION

Electrical stimulation of branches of the pudendal nerve in all experiments led to the appearance of high-amplitude potentials in the urethral sphincter muscles. Since the shape of the potential varied essentially from one experiment to another and also in the course of the same experiment (Fig. 1A), to assess the magnitude of the reflex response, we integrated the response over a period of 50 msec from the time of stimulation.

M. F. Vladimirskii Moscow Regional Clinical Research Institute. (Presented by Academician V. N. Chernigovskii.) Translated from Byulleten' Eksperimental'noi Biologii i Meditsiny, Vol. 68, No. 10, pp. 25-28, October, 1969. Original article submitted March 18, 1969.

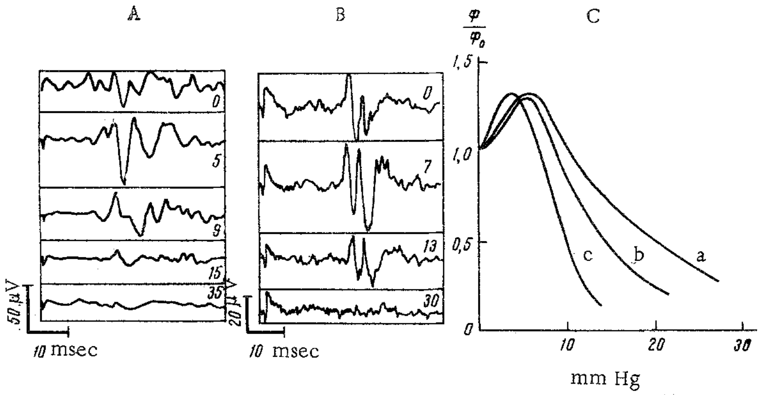

Fig. 1. Change in sphincter response to single electrical stimulation of central end of divided pudendal (A) and pelvic (B) nerve during an increase in intravesical pressure. Numbers on frames show intravesical pressure (in mm Hg); C—mean amplitude of sphincter response (Φ/Φ_0) to stimulation of pudendal (a) and pelvic (b) nerves and also of background activity of sphincter (c) as a function of intravesical pressure (abscissa).

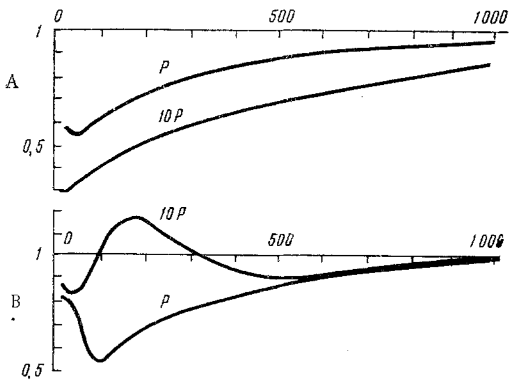

Fig. 2. Changes in excitability of motor center of urethral sphincter in response to conditioning stimulation of pudendal (A) and pelvic (B) nerves by electrical pulses of threshold (P) and maximal (10P) strength. Abscissa, intervals between pulses (in msec); ordinate, mean relative amplitude of response to test stimulation of pudendal nerve.

With the bladder emptied, the threshold amplitude of stimulation averaged 0.1 V and the latent period 13 msec. The sphincter response reached a maximum when the amplitude of the stimulating pulse was 8 times above the threshold level.

A previous investigation showed that with an increase in intravesical pressure, the activity of the sphincter in 17% of experiments was almost zero and remained unchanged, in 33% of experiments it was inhibited, and in 50% of experiments it underwent biphasic changes: it increased when the pressure was low and was inhibited when the pressure was high. In the experiments now being discussed, similar changes in background activity took place. However, irrespective of this, the sphincter response to electrical stimulation of the pudendal nerve had increased in all experiments when the intravesical pressure was low, and it was reduced, and ultimately disappeared completely, when the pressure was high (Fig. 1A). The relationship between response amplitude and intravesical pressure is shown in Fig. 1C (curve a) as the mean of 12 experiments. The mean relationship between background activity and intravesical pressure is also given in the same figure (curve c).

Unlike the response to stimulation of the pudendal nerves, the response of the sphincter to stimulation of branches of the pelvic nerve appeared only if the stimulating electrodes were applied to thick branches of the pelvic plexus. Its amplitude was smaller and its latent period (mean 20 msec) and duration were longer. With the bladder empty the mean threshold of stimulation was 1 V, and the response amplitude reached a maximum when the strength of stimulation was 10 times above the threshold. With an increase in intravesical pressure the response of the sphincter to stimulation of the pelvic nerve underwent the same changes as that to stimulation of the pudendal nerve: with a low intravesical pressure an increase in the integral response was observed, but when the pressure was high the response was reduced (Fig. 1B and C, curve b).

A reflex increase in sphincter activity in response to electrical stimulation of the pelvic nerve of high intensity conflicts with the results of experiments with adequate stimulation of the bladder receptors, demonstrating the inhibitory action of a strong stimulus [3]. This contradiction can be explained on the assumption that afferent impulses from the bladder have a relatively weak action, with a low threshold of excitation, on the sphincter motoneurons, and also an inhibitory action, with a high threshold and developing later. To test this hypothesis a series of experiments was carried out in which changes in excitability of the motor centers of the sphincter were studied in response to conditioning stimulation of the pudendal (Fig. 2A). and pelvic (Fig. 2B) nerves. The level of excitability was assessed from the relative amplitude of the response to test stimulation of a branch of the pudendal nerve, applied at an interval of 20-1000 msec after the conditioning stimulus. With an interval of less than 20 msec, in a series of experiments superposition of the effects produced by both stimuli was observed, and it was impossible to calculate the amplitude of the response to the test stimulus.

Threshold (P) and maximal (10P) stimulation of the pudendal nerve lowered the excitability of the motor center of the sphincter (Fig. 2A). Excitability was least when the duration of the interval was 20 msec. An increase in duration of the interval was accompanied by gradual recovery of excitability. If the amplitude of the stimulating pulse was high (10P), a greater decrease in excitability was observed over a longer period of time.

If the conditioning stimulus was applied to the pelvic nerve, the pattern of change in excitability was more complex than during stimulation of the pudendal nerve. For example, in response to stimulation of near-threshold value (P), a decrease in excitability was observed in the interval of 20-100 msec after the conditioning stimulus, while in the interval of 100-1000 msec, the level of excitability returned steadily to its initial value (Fig. 2B). In the case of maximal stimulation of the pelvic nerves (10P), with intervals of 20-50 msec a slight decrease in excitability was observed, with intervals of 50-200 msec excitability increased and actually exceeded its initial level, and with intervals of 200-500 msec, it fell again below its initial level, after which it slowly recovered. Similar changes in excitability of the motor center were discovered in experiments in which stimulation of the pelvic nerves was used as both conditioning and testing stimulus.

Comparison of the results illustrated in Fig. 2A and B indicates the different character of changes taking place in excitability in response to stimulation of the pudendal and pelvic nerves. Gradual recovery of the initial level of excitability after stimulation of the pudendal nerve (Fig. 2A) corresponds to the after-depression of motoneurons as a result of their strong excitation, described by other workers [1, 5].

The change in excitability in response to weak stimulation of the pelvic nerve has much in common with the picture of after-depression (Fig. 2B, curve P). With high amplitude of the stimulating pulse, the shape of the curve in excitability is modified by the appearance of a positive phase in the interval 100-200 msec (Fig. 2B, curve 10P). This picture can apparently be obtained as a result of superposition of after-depression caused by excitation of motoneurons and temporary exhaltation ("positive rebound" [4]), connected with the development of the inhibitory action of strong (10P) electrical stimulation of the pelvic nerves. Changes of this type in excitability of the spinal cord motoneurons to stimulation of the pelvic nerves have also been observed by other workers [6, 7]. However, the mechanism of this phenomenon has not yet been explained.

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