PHYSIOLOGY

ELECTROPHYSIOLOGIC CHARACTERISTICS OF INTEROCEPTIVE REFLEX ARC

COMMUNICATION I. CHARACTERISTICS OF REFLEXES ARISING ON STIMULATION OF BLADDER MECHANORECEPTORS

T. S. Lagutina

Laboratory of General Physiology (Head – Active Member AMS USSR V. N. Chernigovsky) and Laboratory of Physiology of the Nervous System (Head – O. V. Verzilova), Institute of Normal and Pathologic Physiology (Head – Active Member AMS USSR Professor V. N. Chernigovsky), AMS USSR, Moscow

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Reflexes arising on stimulation of various interoceptive areas have been well studied but there are still no complete data on processes occurring in various links of the interoceptive reflex arc during the appearance and development of an interoceptive reflex.

In order to study the processes which take place in the interoceptive reflex arc the reflexes associated with stimulation of the bladder mechanoreceptors were selected in the present work. Physiologic investigations and clinical data provide evidence of complex reflex connections between the organs of the excretory system in the first place. Thus, Barrington [7, 8] described a series of reflexes appearing in cats during the act of micturition: reflex contraction of the bladder associated with the passage of fluid through the urethra; reflex relaxation of the urethra during the passage of fluid through it; reflex relaxation of the urethra accompanying distention of the bladder musculature.

Other authors studied action potentials in afferent and efferent fibers of the bladder [10, 12].

It was shown that depending on the functional state of the central nervous system micturition can occur at different degrees of filling of the bladder [2, 3, 9, 11].

N. A. Adamovich [1], who studied afferent impulses in the branches of the pelvic nerve which innervates the bladder noted that the intensiveness of efferent activity in the pelvic nerve depended not only on the intensiveness of afferent activity from the bladder but also on the state of the central nervous system. When the excitability of the centers had been artificially increased by strychnine the efferent activity in the pelvic nerve was considerably enhanced and could even be observed when the bladder was empty.

Stimulation of the bladder mechanoreceptors leads not only to reflex contraction of its musculature and to reflex changes in the tonus of the urethra but also produces reflex changes in other systems of the organism. Changes in blood pressure, respiration, activity of smooth and skeletal muscle etc. may occur during stimulation of the bladder mechanoreceptors. Some time ago V. N. Chernigovsky [4, 5] had suggested that two types of interoceptive reflexes be recognized – "direct" and "conjugated". The former are reflexes directly connected with a given physiologic system and discharged within its limits, mediating a definite group of reflexes "serving" the given system. The latter, also arising from the given interoceptive area, are discharged outside the given

physiologic system and involve in the reaction physiologic systems which are not directly connected with the first one in a functional sense.

Subsequently V. M. Khayutin [6] established that "direct" reflexes (from the bladder mechanoreceptors to urethral tonus) had a 2-7 times lower threshold than the "conjugated" reflexes (from the bladder mechanoreceptors to blood pressure and respiration) and were much less subject to adaptation on prolonged stimulation of the bladder mechanoreceptors. Reflexes described by Barrington should be regarded as "direct".

In the present communication data are presented concerning the electrophysiologic characteristics of "direct" reflexes primarily (the electrophysiologic analysis of "conjugated" reflexes will form the substance of further communications).

METHODS

Experiments were performed on cats. Intravenous urethane anesthesia was used. In order to stimulate the bladder mechanoreceptors it was filled with physiologic solution or with air. A cannula was introduced into the bladder through the urethra; the cannula was connected by a three-way tap with a system of vessels used for inflation and with a mercury manometer which registered pressure within the bladder. The tonus and contractions of the urethra were recorded by the method described by V. M. Khayutin [6]. In these experiments carotid artery blood pressure was also recorded (mercury manometer).

Simultaneously with the recording of blood pressure and urethral tonus a record was taken of the electric potentials in the peripheral end of a branch of the pelvic nerve leading to the bladder (afferent impulses from bladder receptors) and in the central end of the pudendal nerve (efferent impulses to the urethra).

Nerve action potentials were led off by means of platinum electrodes with an interelectrode distance of 4-5 mm; a two-channel cathode oscillograph "OB-2" and amplifier were used. The frequency characteristic of the amplifier was linear within the range of 10-500 cps.

RESULTS

Recording of action potentials from the peripheral end of the pelvic nerve (afferent impulses from the bladder) when the bladder was empty showed that electric activity was absent from the nerve, which is in accordance with the data of other authors. At the same time continuous impulses were observed in the central end of the pudendal nerve; these impulses increased somewhat when physiologic solution was allowed to flow through the urethra. Introduction of from 2 to 10 cc of air (different quantities in different experiments) into the bladder gave rise to considerable increase of afferent impulses in the pelvic nerve. The central reaction in response to this stimulation was an increase in the frequency and amplitude of efferent impulses in the pudendal nerve. The latent period of the change in efferent impulses following the beginning of stimulation of the bladder mechanoreceptors was from 2 to 7 seconds. There was simultaneous increase in the tonus and contraction of the urethra (Fig. 1).

Thus the first reflex which appears on weak stimulation of the bladder mechanoreceptors is an increase in the tonus of the urethra.

There are no changes in blood pressure.

Increasing the intensity of stimulation of the bladder mechanoreceptors (introduction of 10-20 cc of air into the bladder) caused strong afferent activity in the pelvic nerve.

In response to increased stimulation there was lowering of efferent activity in the pudendal nerve.

On further increasing bladder stimulation efferent impulses in the pudendal nerve ceased altogether. The latent period for change in efferent activity remained the same. During this time decrease of urethral tonus, i.e., its relaxation, was observed (Fig. 2). No changes in blood pressure occurred with this strength of stimulation.

Only on still further increase in the strength of stimulation did a rise in blood pressure take place together with complete depression of efferent impulses and relaxation of the urethra, i.e., the reflex influences spread not only to the system directly related to the performance of the given function, but also involved a system further removed in a functional sense.

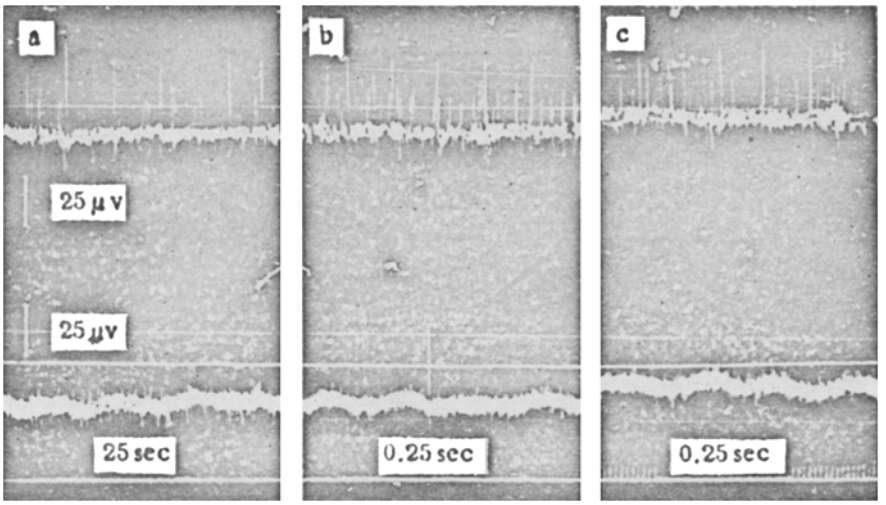

Fig. 1. Reflex changes in urethral tonus and afferent and efferent impulses on weak stimulation of the bladder mechanoreceptors.
a) Initial efferent impulses in the pudendal nerve with a rhythm of 60 per second. Afferent impulses in the pelvic nerve are absent (before stimulation); b) 9 cc of air introduced into the bladder; efferent impulses in the pudendal nerve with a rhythm of 100 per second. Afferent impulses in the pelvic nerve represented on the oscillogram by several impulses; c) the same 5 minutes after withdrawal of air from the bladder; efferent impulses in the pudendal nerve with a rhythm of 70 per second; afferent impulses in the pelvic nerve absent. Records from above down: acion potentials of the central end of the pudendal nerve; action potentials of the central end of the pelvic nerve; time marker (0.25 seconds).

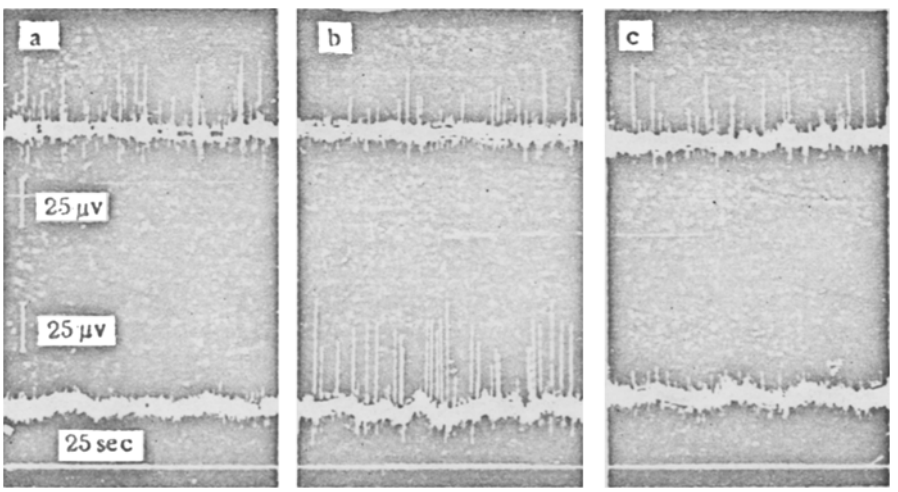

Fig. 2. Reflex changes of urethral tonus and of afferent and efferent impulses on stronger stimulation of the bladder mechanoreceptors.
a) Initial efferent impulses in the pudendal nerve with a rhythm of 70 per second. Afferent impulses in the pelvic nerve absent (before stimulation); b) 11 cc air introduced into the bladder; efferent impulses in the pudendal nerve at 32 per second; appearance of considerable afferent activity in the pelvic nerve; c) the same 5 minutes after withdrawal of air from the bladder; efferent impulses in the pudendal nerve with a rhythm of 55 per second; afferent impulses in the pelvic nerve absent. Records the same as in Fig. 1.

In order to trace the part played in natural micturition by those reflex relations between the bladder and

the urethra which were observed in the present work with various degrees of filling of the bladder, special experiments were performed in which the abdominal cavity was opened with great care. In those cases in which the bladder proved to be filled with urine afferent impulses were recorded from the pelvic nerve and efferent impulses from the pudendal nerve.

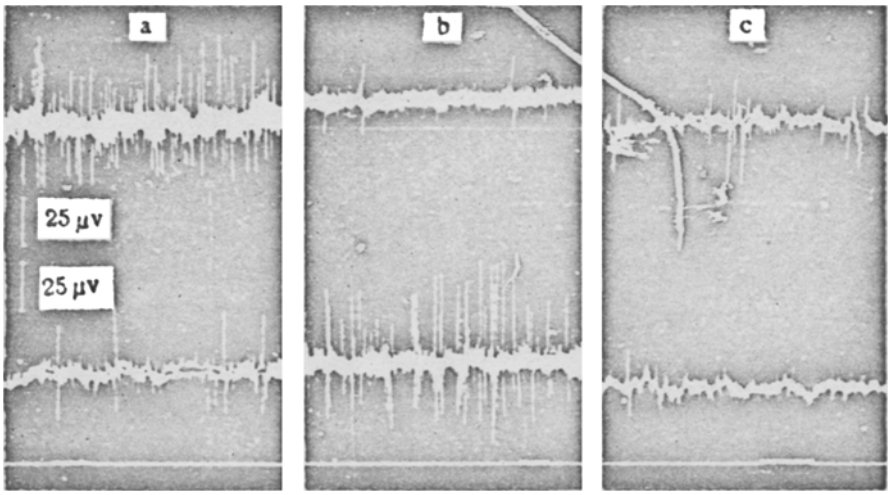

Fig. 3. Reflex effects from the bladder on urethral tonus; efferent and afferent impulses during natural micturition.
a) Bladder is filled with urine, but is relaxed; strong efferent activity is seen in the pudendal nerve and weak afferent activity in the pelvic nerve;
b) contraction of the bladder during micturition; sharp lowering of efferent activity in the pudendal nerve; intensive afferent activity in the pelvic nerve;
c) the same after emptying of the bladder; efferent impulses in the pudendal nerve present but considerably weaker than with full bladder; afferent impulses in the pelvic nerve practically absent; records the same as in Fig. 1.

Figure 3,a shows that if the bladder is filled but relaxed low frequency afferent activity occurs in the pelvic nerve. At the same time strong efferent impulses to the urethral musculature is observed in the pudendal nerve and it is evidently these impulses that maintain the urethra in the contracted state, thus preventing the escape of urine from the bladder. Further filling of the bladder is thus possible.

However, when the bladder reaches certain dimensions its contraction begins. As can be seen from Fig. 3, b, contraction of the bladder gives rise to considerable afferent activity in the pelvic nerve under the influence of which a sharp decrease in the efferent activity with respect to urethral musculature and its relaxation occur. This mechanism ensures emptying of the bladder. Following evacuation of the bladder (Fig. 3, c) efferent impulses to urethral musculature are decreased considerably as compared to impulses seen when the bladder is full (Fig. 3, a).

At this moment, as shown by V. M. Khayutin [6], if the outflow of urine is blocked, a rise of blood pressure takes place.

DISCUSSION

The results obtained show that two opposite reactions of the urethra can be obtained on simultaneous recording of afferent impulses from the bladder and efferent impulses to the urethral musculature, as well as of urethral tonus and blood pressure, depending on the strength of stimulation of the bladder mechanoreceptors.

Weak stimulation of bladder mechanoreceptors gives rise to insignificant afferent impulses in the pelvic nerve. Reaching the centers, they elicit a state of excitation if the state of the centers is judged by the efferent impulses in the pudendal nerve, since the latter are increased. It must be supposed that this reflex underlies the mechanism of bladder filling up to a definite volume. This volume varies not only in different animals but also in one and the same animal depending on the functional state of the central nervous system [2, 3, 9, 11].

Increased stimulation of the bladder mechanoreceptors leads to the appearance of intensive afferent activity in the pelvic nerve which also finds its way to the centers. In this case this activity evidently leads to the development of inhibition, since efferent impulses in the pudendal nerve become markedly weaker or cease altogether. Dilatation of the urethra follows cessation of efferent activity in the pudendal nerve supplying the urethral musculature. It is this reflex which makes reflex emptying of the bladder possible. The role of this reflex in micturition has been studied previously [6, 7, 8, 10].

Both these reflexes fit into the framework of "direct" reflexes. Further increase in the strength of stimulation of the bladder mechanoreceptors in the present experiments gave rise to changes in blood pressure in addition to complete inhibition of efferent impulses and relaxation of urethral tonus.

Consequently, both these "direct" reflexes are at the basis of micturition. Until the intensiveness of impulses in the afferent fibers reaches a definite strength, efferent impulses maintain the urethra in a state of active contraction. Only on further increasing the strength of stimulation does inhibition of efferent impulses occur. This inhibition, as already suggested, occurs as a consequence of inhibition of relevant centers.

On still further increase of stimulation inhibition in the "centers" of the "direct" reflex becomes still more profound and a "conjugated" reflex appears — a rise in blood pressure, i.e., excitation spreads to other centers.

These data confirm the presence of lower thresholds for "direct" reflexes as established by V. M. Khayutin [6], as well as the general thesis concerning "direct" and "conjugated" reflexes proposed by V. N. Chernigovsky [4, 5].

SUMMARY

Afferent impulsation in the peripheral end of a pelvic nerve branch and efferent impulsation to the urethra in the central end of the pudendal nerve have been recorded in the course of short experiments on cats. Pressure in the urinary bladder, blood pressure and contractions of the urethra have been simultaneously registered. Slight distention of the urinary bladder to 10-20 mm Hg by inflation of 2-10 cc of air caused insignificant afferent impulsation in the pelvic nerve, increased the frequency and amplitude of efferent impulsation in the pudendal nerve, and a rise of the tonus and contractivity of the urethra. Distention of the urinary bladder to 20-30 mm Hg by inflation of 10-20 cc of air intensified afferent impulsation in the pelvic nerve, lowered efferent impulsation in the pudendal nerve down to complete cessation and relaxation of the urethra. Excitation of intermediate degree led to rhythmic bursts and depression, likewise to alternating contraction and relaxation of the urethra. The same three phases have been noted during natural urination.

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