SPONTANEOUS POTENTIAL ACTIVITIES RELATED TO THE INTRAVESICAL PRESSURE IN THE PONTINE AREA OF THE CAT

Kentaro Koshino, M.D.

Kansai Medical College, Department of Neurosurgery

Studies on the afferent nerve pathways from the urinary bladder have been reported, but are still in the main part uncertain. Kuru and his associates (1940, 1947, 1949, 1951, 1956, 1965) made it clear anatomically, by the Marchi stain technique, that the pelvic nerves, which belong to the most important afferent pathways of the urinary bladder, travel by two different tracts in the spinal cord. One of them ascends in the dorsal column and the other, as the secondary fibers of the sacrobulbar tract, travels in the lateral column. Both of them terminate in the medulla oblongata. Yamamoto et al (1956) recorded impulses responding to the filling of the urinary bladder from the surface of the middle of the dorsal column at the level of the upper cervix. Kamikawa et al (1962) recorded action potentials in the lateral column at the lumbar level associated with the change of intravesical pressure. Tokunaga (1956), with electrical stimulation, certified the existence of the vesicodilator area in the lateral nuclei of the medulla oblongata and the vesicodilator area in the dorsomedial part of the reticular formation of the medulla. Kamikawa et al (1959, 1962) also succeeded in recording the action potentials, which corresponded to the filling of the urinary bladder, in both the vesicodilator and vesicoconstrictor areas of the medulla. Barrington (1925) experimentally confirmed in the cat that the bilateral lesions in the medial part of the mesencephalic trigeminal nucleus at the level of rostral pons make it impossible to urinate sufficiently and that the bilateral lesions of the ventrolateral portion of the central gray at the level of the lower midbrain cause loss of the filling-sensation of the urinary bladder. Yamamoto (1962) anatomically clarified the fiber connections, which Barrington pointed out, from these two locations using the Marchi stain technique that the ascending fibers connect to the midbrain and to the thalamus via the tegmental bundle of Forel's and that the descending ones connect, not only to the vesicoconstrictor and vesicodilator centers of the medulla, but also

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directly to the center of vesical movements at the sacral cord, partly joining to the lateral reticulospinal tract. IKEDA (1962) recorded evoked potentials from these fibers by stimulation of the central cut end of the pelvic nerve, which originate from the terminal of the spinobulbar tract and join the tegmental bundle of Forel's.

The present study was attempted to record the action potentials in the tegmental bundle of Forel's which correspond to the physiologic movements of the urinary bladder.

**METHOD**

The experiments were carried out in 26 adult cats weighing from 1.5 to 4 kg. The animals were anesthetized with chloralose (30 mg/kg i.p.). Artificial respiration was used through tracheotomy when necessary. After urethrotomy was performed, the catheter was connected with a T-tube, one arm of which was attached to a manometer for electrical recording of intravesical pressure. Intravesical pressure was recorded in the oscilloscope connected to the electric manometer (MP-4 type, Nihonkoden). The other arm was connected, through a three way-stopcock, to a reservoir filled with warm saline that could be introduced into the bladder. In some cases the three way-stopcock was closed to produce a relatively "isovolumetric" contraction. Decerebration at the level of rostral portion of superior colliculus or intercollicular decerebration was carried out, and cerebellum was also removed in order to expose the fourth ventricle floor. Warm liquid paraffin was poured over the fourth ventricle floor to keep it wet.

After the cat was fixed to the stereotaxic apparatus, the electrode was inserted at random into the floor of the fourth ventricle to obtain the action potentials corresponding to the intravesical pressure. The recording electrodes were insulated with synthetic resin except the tip of 10 μm in diameter. A one cm square silver plate was attached under the edge of wound as an indifferent electrode. Action potentials were recorded, together with the intravesical pressure, in Nihonkoden VC-6 type anode oscilloscope with electrobiological amplifier. After recording, a small lesion by electrocoagulation was made at the tip of the electrode to identify the recording site. At the end of the experiment, the brain stem was fixed with 10% formalin and then submitted to histological procedure to determine the localization of the electrodes.

**RESULTS**

After injection of the 20-30 cc warm saline into the urinary bladder, spontaneous rhythmical movements of the bladder occurred with a cycle of 17-44 sec irrespective of the respiratory movements, and the changes of intravesical pressure ranging from 3 to 7 cm H₂O were produced. Then, the recording electrode was inserted at random in the pons and the rostral part of the medulla.

The spike discharges observed are classified as follows:

1) irregular spike discharges irrespective of the movements of the urinary bladder and respiration

2) spike discharges corresponding to the respiratory movements
3) spike discharges corresponding to the intravesical pressure
   (A) spike discharges corresponding to the spontaneous contraction of the urinary bladder

   The following results were obtained from 54 recording points in 26 cats, out of which 45 were histologically investigated. Negative and positive spikes were obtained and their amplitudes ranged from 50 to 200 μv.

   Following two types of correlation existed between intravesical pressure and discharge frequencies.
   a) increase of the discharge frequency associated with the increment of intravesical pressure.

   In 29 out of the 54 points, the increase of discharge frequency began just before the increment of intravesical pressure and kept increasing concomitant with the latter. At the maximum point of intravesical pressure, the discharge frequencies had already decreased (Fig. 1).

   b) increase of the discharge frequency corresponding to the decrement of intravesical pressure.

   Fig. 1. (A) Action potentials corresponding to increase of the intravesical pressure. Increment of the frequencies of the action potentials with the spontaneous contraction of the urinary bladder. The upper line shows the intravesical pressure: upward is the increment of pressure. The lower line shows the action potentials recorded in the brain stem. Upward is positive in all figures. (B) Histology indicating the recording point.
25 points were grouped in this category. The discharges gradually increased with the decrement of the intravesical pressure, kept firing during the low pressure and decreased with a rise in the intravesical pressure (Fig. 2).

FIG. 2. (A) Increment of the action potentials associated with the decrement of the spontaneous contraction of the urinary bladder. The upper line shows the action potentials, the lower line shows the change of intravesical pressure. (B) Histology indicating the recording point.

(B) spike discharges corresponding to the isovolumetric contraction of the urinary bladder

When the spike discharges corresponding to the spontaneous change of the intravesical pressure were obtained, the three way-stopcock was closed to produce "isovolumetric" contraction and the change of the discharge frequencies was observed. There were two different types of responses.

a) Change of the discharge frequencies associated with the spontaneous contraction of the urinary bladder was still observed even in the isovolumetric contraction (9 points).
b) The frequency change observed in the spontaneous contraction disappeared at the time of the isovolumetric contraction (2 points).

(C) spike discharges corresponding to the passive change of the intravesical pressure

The intravesical pressure was passively changed by injecting or withdrawing warm saline drop by drop. The same results as were obtained in the spontaneous change were seen in the passive change.

45 points were histologically investigated: at 24 points the increase of the discharge frequency corresponded to the increment of intravesical pressure, and at 21 points the increase of the discharge frequency corresponded to the decrement of intravesical pressure.

Histologically the dorsal view shows that these points are mostly located along the midline and sulcus limitans from the upper part of the medulla to the rostral part of the pons (Fig. 3). On the frontal section, most of them are located in the dorsolateral part of the reticular formation of the medulla.

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**Fig. 3.** Schematic representation of bulbo-pontinal distribution of the responded spots. The left figure shows the dorsal projection of the brain stem. Open circles show the point at which the increment of action potentials occurred concomitant with the increment of intravesical pressure. Solid circles show the point of the increment of action potentials associated with the decrement of intravesical pressure. Open circles are projected in the left side of the brain stem and solid circles in the right side. The right figure shows the frontal projection of the brain stem.
and the tegmentum of the pons, and the dorsal part of the raphe close to the central gray (Fig. 3). These anatomical localizations are consistent with the pathway of the tegmental bundle of Forel's. There is no significant difference in the histological location between the increase of the discharge frequency during the increment of intravesical pressure and that during the decrement of it.

**DISCUSSION**

Stella (1934) clarified the existence of the receptor in the urinary bladder of the frog which responds to the movement of the bladder wall. The impulses recorded from the pelvic nerve increased concomitantly with the passive distension of the urinary bladder and, moreover, the tension of the strip which composed the bladder wall increased the frequencies of the spike discharges. Evans (1936) insisted that the afferent impulses of the urinary bladder in the cat originated from the stretch receptor in the bladder wall because the impulses recorded from the pelvic nerve were observed with the increment of intravesical pressure and they disappeared with the abrupt decrement of the pressure. Talaat (1937) found that there were two sensory end organs in the dog, one of which responded to the contraction of the urinary bladder and the other responded to the dilatation, and that the speed of response was faster in the former than in the latter. Kamikawa (1959) also recorded two types of responses in the medulla of the cat; one of them increased the spike discharges and the other decreased them in relation to filling of the urinary bladder. Matsuo (1959) obtained the same result as Kamikawa did in the lumbar cord. In the present study, two types of responses were observed in the spike discharges related to the vesical movement in the pontine area. These observations confirm that two different types of responses exist and travel through the spinal cord at least up to the pontine level. Iggo (1954, 1955) recorded the impulses from the pelvic nerve of the cat which responded not only to the passive distension, but also to the active contraction of the urinary bladder and thus concluded that the receptor of the urinary bladder was the tension receptor which was "in series" with the muscle fiber. In the present experiment also the increment of spike discharges corresponding not only to the isovolumetric contraction of the urinary bladder, but also to the passive distension was observed. This fact implies that the receptor is "in series" with the muscle fiber of the urinary bladder as Iggo mentioned. Additionally, the fact that the discharge frequencies increased in the spontaneous contraction and decreased in the isovolumetric contraction suggests that the receptor is considered to work as a volume receptor, or to be "in parallel" with the muscle fiber.

Yamamoto (1962) clarified centrifugal and centripetal fiber connections
from the contraction center of urinary bladder in the pons of the cat with the Marchi stain, which is described by Barrington. According to him, the descending fibers end in the ipsi- and contra-lateral vesicoconstrictor and vesicodilatator center in the medulla and, additionally, a part of them directly get to the spinal cord at the level of sacrum together with the lateral reticulospinal tract. On the other hand, the ascending fibers connect to the mesencephalic vesicoconstrictor center and after that, terminate in the mesencephalic central gray and ventrolateral nucleus of the thalamus. These anatomical pathways are consistent with the locations from which the action potentials were recorded in relation to the intravesical pressure. On the basis of these findings, it is proved that the afferent fibers corresponding to the intravesical sensation mediate the tegmental bundle of Forel’s.

According to Mellanby (1939), the amplitude and regularity of rhythmic activity of the urinary bladder greatly depend upon the kind of anesthetics and the depth of anesthesia. In this study the anesthetization was discontinued after decerebration and the experiment started after the drug effect completely expired. So the drug effect on the urinary bladder activity are out of the question here.

The problem of the regulation of the afferent impulses originating from the urinary bladder has not been investigated yet, but at least, up to now we could assess that there are two types of receptors in the urinary bladder one is for tension and the other for volume, and the afferent impulses from these two receptors are once transmitted to the terminal nucleus of the sacrobulbar tract and then travel to the tegmental bundle of Forel’s. After that, there is no doubt that they are transmitted to the motor center of the urinary bladder in the pons and mesencephalon.

CONCLUSION

1. Action potentials corresponding to the change of intravesical pressure in the pons and the rostral part of the medulla were recorded in 26 adult cats and also their localizations were verified histologically.

2. Responses are divided into two types: 1) increase of the discharge frequencies associated with the increment of the intravesical pressure. 2) increase of the discharge frequencies associated with the decrement of the intravesical pressure.

3. At 9 points out of the recorded 54 points the frequency change of spike discharges related to the spontaneous contraction of the bladder was still observed even in the isovolumetric contraction. On the contrary, in 2 points, the responses of spike discharge associated with the spontaneous contraction disappeared in the isovolumetric contraction. This fact suggests that two types of receptors exist: the one relates to the intravesical pres-
sure, and the other to the volume of the urinary bladder.

4. Histologically the location of the points where the action potentials corresponding to the change of intravesical pressure were recorded originates in the terminal of spinobulbar tract and is consistent with the ascending fibers which join the tegmental bundle of Forel’s. This fact confirms that the tegmental bundle of Forel’s contains the afferent fibers from the urinary bladder.

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