ELECTROTONIC POTENTIALS OF PRIMARY VAGUS NERVE ENDINGS AND THE HERING-BREUER INHIBITORY REFLEX

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The primary afferent depolarization caused by stimulation of the vagus nerve is ill defined when tested on the P wave of the electrotonic potential. The Hering–Breuer inhibitory reflex is evidently due to strychnine-resistant postsynaptic inhibition.

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It has been shown [3] that strychnine has no effect on the Hering–Breuer inhibitory reflex. Even after injection of subconvulsive doses of strychnine, stretching of the lungs as a rule caused respiratory arrest and relaxation of the diaphragm. According to Eccles [4], postsynaptic inhibition is blocked by strychnine. On these grounds, inhibition which is not blocked by strychnine is regarded by Eccles as presynaptic inhibition, caused by primary afferent depolarization (PAD) of the endings. The Hering–Breuer inhibitory reflex is caused by impulses arriving from the stretch receptors of the lungs and spreading along afferent fibers of the vagus nerve [2].

The object of the present investigation was accordingly to study the PAD of vagus nerve endings.

EXPERIMENTAL METHOD

Experiments were performed on 20 cats weighing from 2 to 4 kg and anesthetized with Nembutal (30 mg/kg). The animals were immobilized with tubarine (1.5 mg/kg) and maintained on artificial respiration. The cat's head was fixed securely in an apparatus designed to turn the whole animal through 360°. Stimulating platinum bipolar electrodes were applied on the central end of the divided vagus nerve in the lower part of the neck. The nerve was stimulated with single square pulses, 0.5 msec in duration, and of maximal strength for excitation of A- or C-fibers. In some experiments, besides single stimuli, volleys of five pulses with a frequency of 500/sec were applied. The afferent input was checked by recording the complex action potential of the vagus nerve with platinum bipolar electrodes placed near the ganglion nodosum. Electrotonic potentials of the vagus nerve endings were recorded by a silver wire electrode in the region of the obex, above the projection of the tractus solitarius. The silver disc reference electrode was placed between the occipital zone and muscles. The vagus nerve was stimulated by means of a type SIF stimulator with a special attachment supplying volleys of pulses. Recordings were made by means of a "DISA" 3-channel amplifier and S1-4 oscillograph.

EXPERIMENTAL RESULTS

Stimulation of the vagus nerve evoked a three-phase spike on the posterior surface of the medulla in the region of the tractus solitarius, followed by a negative N wave and positive P wave. The spikes and N waves appeared in response to threshold stimulation of group A fibers, and in response to supramaximal stimulation of the A-fibers their amplitude increased and a P wave appeared. With an increase in strength of the current to involve C-fibers, no changes were observed in the electrotonic potential of the vagus nerve.

In contrast to the potential of the posterior surface of the spinal cord, the N and P waves of the electrotonic potential in the region of the tractus solitarius were ill defined (Fig. 1A). The amplitude of the N wave was 15-75 μV and its duration varied from 16 to 25 msec. The latent period of the N wave was 0.5-1.5 msec. The amplitude of the P wave varied from 12.5 to 50 μV and its duration was 50-160 msec. In some experiments no P wave could be recorded. Stimulation of the vagus nerve with a volley of pulses

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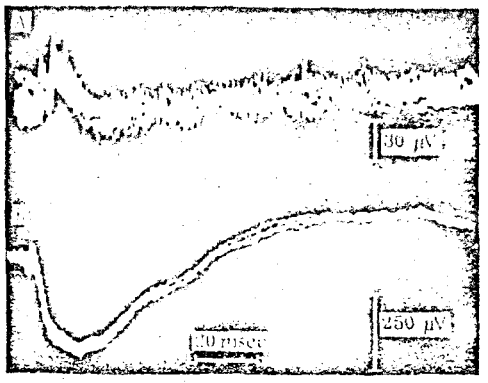

Fig. 1. Electrotonic potentials in region of tractus solitarius of a cat caused by stimulation of left vagus nerve (nine sweeps of the beam; A) and of the left superficial radial nerve (three sweeps of the beam; B).

caused no increase in the P wave. The responses likewise were not increased by intravenous injection of subconvulsive doses of strychnine, and only convulsive doses of strychnine in some experiments produced a barely perceptible increase in the P wave. Maximal responses were found in the region 1-2 mm cranially and 2-3 mm laterally to the obex. The responses were recorded on the side of the stimulated nerve. When the contralateral nerve was stimulated, no response was found in this region.

No changes in electrotonic potentials with the phases of respiration could be found.

In contrast to the effects of stimulation of the vagus nerves, stimulation of the superficial radial nerve evoked a distinct P wave in this same region (Fig. 1B).

In accordance with Eccles's conception, PAD causes presynaptic inhibition. It is well known that the P wave of the potential of the dorsal surface of the spinal cord reflects PAD of the endings of the dorsal spinal roots. This idea was subsequently developed in relation to the P wave of electrotonic potentials of the nuclei of the posterior columns [4] and the nuclei of the trigeminal nerve [6]. It may be supposed that the P wave of the electrotonic potential evoked by stimulation of the vagus nerve also reflects PAD of the vagus nerve endings.

The P wave of the electrotonic potential on the surface of the medulla recorded in the region of the vagus nerve endings is ill defined or absent. This is particularly clear when it is compared with the P wave evoked by stimulation of the superficial radial nerve, endings of which terminate in the nucleus cuneatus, located in the immediate proximity of the nucleus solitarius.

For this reason, presynaptic mechanisms evidently do not participate in the Hering–Breuer inhibitory reflex, or if they do they play only a minor role. This inhibition is probably due mainly to postsynaptic mechanisms, and it may possibly be an example of the recently described strychnine-resistant postsynaptic inhibition [5].

The absence of a clearly defined PAD of the vagus nerves is evidently for a good reason, because PAD of the vagus nerve endings would block the flow of impulses from the stretch receptors of the lungs, and would thus prevent manifestation of the Hering–Breuer reflex, the principal reflex responsible for the self-regulation of respiration [1].

The experiments described above are also interesting in connection with the problem of presynaptic inhibition as a whole. PAD is best produced by stimulation of the skin, and not nearly so well by stretching muscles. This has also been found in the case of electrical stimulation of nerves. A single stimulation of cutaneous afferent nerves is sufficient to evoke PAD. A volley of pulses must be applied to produce PAD from muscle afferents [4]. During stimulation of autonomic nerves (afferents of the vagus nerve), the PAD is least evident. Reflexes elicited from the skin, which is subjected to numerous influences, possibly require stronger inhibition than reflexes from the internal milieu, characterized by its greater constancy. To confirm this hypothesis, besides indirect investigations of PAD by recording electrotonic potentials on the surface of the medulla, direct investigation of depolarization of the vagus nerve endings is necessary.

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