Why do patients with respiratory muscle paralysis require artificial hyperventilation?

S.I. Frankstein, T.I. Sergeeva and Z.N. Sergeeva

Institute of General Pathology, Academy of Medical Sciences, Baltijskaya 8, Moscow (USSR), 10 August 1978

Summary. The primary reason for the need of hyperventilation in patients with respiratory paralysis is the insufficiency of the inhibitory Hering-Breuer reflex. The artificial distension of the lungs with normal tidal volume cannot inhibit the respiratory centre in contrast to the normal state.

In patients with respiratory muscle paralysis, artificial lung ventilation may maintain normal blood gas tension, although the patients feel a respiratory discomfort. To prevent this, the patients need an additional lung ventilation. The additional ventilation causes hypocapnia, as a result the sensitivity of the respiratory centre to CO_2 increases. Therefore (as is generally accepted) the patients need hyperventilation[1,2]. But what is the reason of the patients' demand for artificial hyperventilation before hypocapnia arises?

To analyse this problem, we investigated the respiratory discharges of the respiratory centre in paralyzed animals. Tubocurarine (1 mg/kg) was administered and artificial respiration was used in all experiments. The experiments were performed on 5 anaesthetized cats (nembutal, 30 mg/kg). The respiratory discharges were recorded from the sternal part of the diaphragm and from the central part of the divided phrenic nerve.

Results and discussion. The paralysis of the diaphragm arises immediately after the injection of tubocurarine; the electrical activity of the diaphragm disappears. In contrast, the activity of the respiratory centre increases – the phrenic nerve discharges are immediately intensified (figure 1).

The second series of experiments was performed on vagotomized animals. Both cervical vagi were cut. The injection of tubocurarine into vagotomized animals causes paralysis of the diaphragm, just as in normal animals: the electrical activity of the diaphragm disappears, but, in contrast to normal animals, the phrenic nerve discharges are not intensified immediately (figure 2).

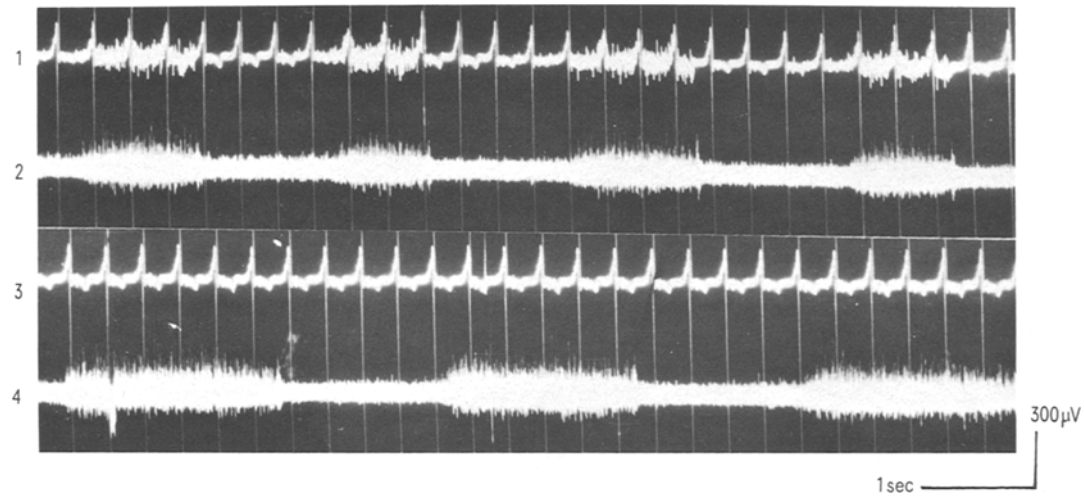

Fig. 1. Before vagotomy. Electrical activity of the diaphragm (1) disappears after the injection of tubocurarine (3). The phrenic nerve discharges (2) are intensified (4).

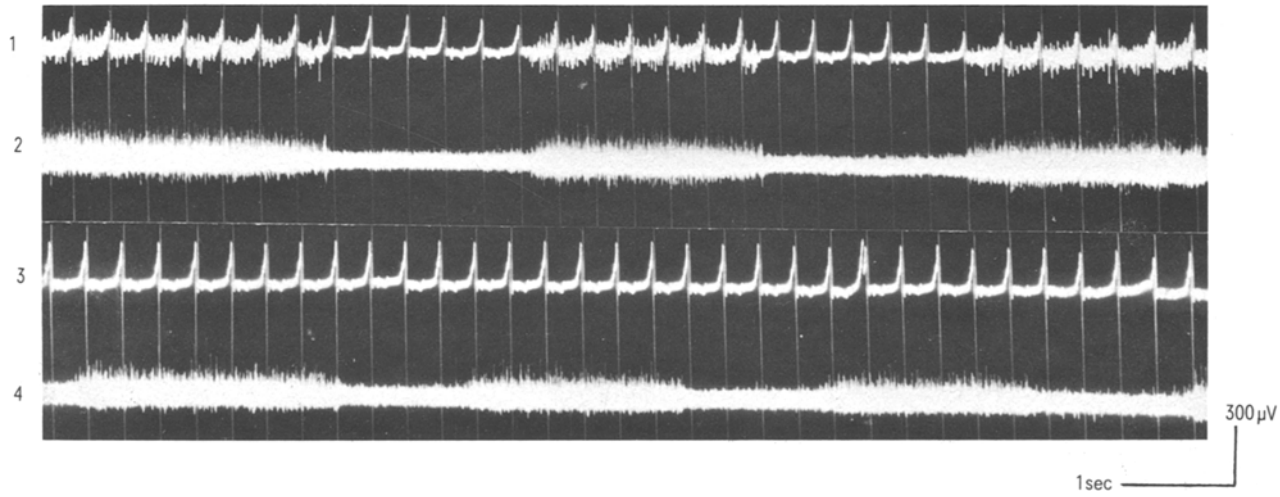

Fig. 2. After vagotomy. Electrical activity of the diaphragm (1) disappears after the injection of tubocurarine (3). The phrenic nerve discharges (2) are not intensified (4).

Thus it is clear that the intensification of phrenic nerve discharges in paralyzed animals depends on the disappearance of impulses from the lung stretch receptors which inhibit the respiratory centre in the normal state.
These experiments suggest the following conclusion. In patients with respiratory paralysis, lung compliance decreases and therefore artificial distension of the lungs with normal tidal volume cannot inhibit the respiratory centre, in contrast to the normal state. Therefore, although blood gas tension is normal, the patients need additional distension of the lungs, additional artificial ventilation. As a result of hyperventilation, $PaCO_2$ decreases and the respiratory centre adapts to hypocapnia, and this in turn creates a need for further hyperventilation. However, the primary reason for the need of hyperventilation in patients with respiratory paralysis is the insufficiency of the Hering-Breuer inflation reflex. – Of course, the results obtained in cats do not entirely justify this conclusion in human beings. Nevertheless it seems to be valid.

1 J.E. Affeldt, in: Handbook of Physiology, sect. 3, vol. 2, p. 1509. Washington 1965.
2 J.H. Auchincloss, in: Handbook of Physiology, sect. 3, vol. 2, p. 1553. Washington 1965.

Hyperventilation and inhibitory synapses

S.I. Frankstein, T.I. Sergeeva and Z.N. Sergeeva

Institute of General Pathology, Academy of Medical Sciences, Baltijskaya 8, Moscow (USSR), 10 August 1978

Summary. Injection of a subconvulsive dose of strychnine (which blocked the inhibitory synapses) increases respiratory muscle activity evoked by stimulation of the sciatic nerve as well as by inhalation of hypercapnic gas mixture. Thus the inhibitory synapses prevent an excessive hyperventilation.

Strychnine is one of the stimulants of the respiratory system. Strychnine blocks the inhibitory synapses[1]. But, as was shown, strychnine does not influence the vagal inhibitory Hering-Breuer reflex[2,3]. Thus it may be supposed that the mechanism of strychnine action on the respiratory system may depend on its anti-inhibitory influence on the motoneurons innervating the respiratory muscles.
To analyse this problem, we investigated the influence of a single subconvulsive dose of strychnine-nitrate (0.07 mg/kg i.v.) (which affects respiration insignificantly): a) on the respiratory reflexes caused by electrical stimulation of the central part of the divided sciatic nerve, and b) on the respiratory muscle activity caused by inhalation of hypercapnic gas mixture.

A pair of stimulating platinum electrodes were placed on the central cut end of the sciatic nerve, and another pair of recording electrodes placed on the sternal part of the diaphragm. For stimulation of the nerve repetitive rectangular pulses, currents of 0.5 msec duration and 10/sec frequency were used. 7% carbon dioxide in oxygen was used. The experiments were performed on 12 cats anaesthetized by urethan (1.5–2.0 g/kg i.v.).
Results and discussion. Before the injection of strychnine, the frequency of respiration was 24.5 ± 1.4 per min. The threshold of the respiratory reflex (the increase of frequency and sometimes the intensity of the diaphragmatic discharges) was 20–30 V. When the stimulation of the nerve was discontinued, increase of diaphragmatic activity

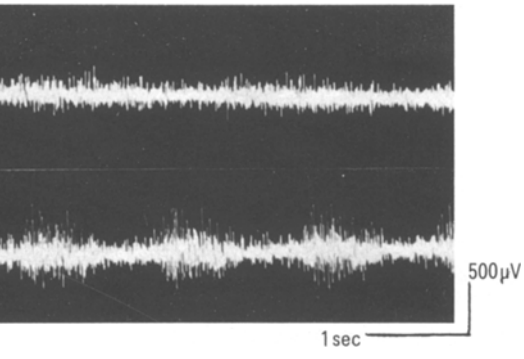

Fig. 1. Before injection of strychnine. Top record: EMG of the diaphragm before inhalation of hypercapnic mixture. Bottom record: inhalation of hypercapnic mixture increases the frequency and intensity of respiratory discharges.

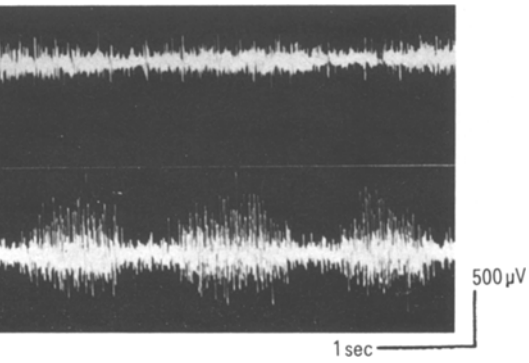

Fig. 2. After injection of strychnine. Top record: EMG of the diaphragm before inhalation of hypercapnic mixture. Bottom record: inhalation of hypercapnic mixture increases the frequency and intensity of respiratory discharges more than in the normal state (figure 1).