THE EFFECT OF ARTIFICIAL PNEUMOTHORAX ON AFFERENT AND EFFERENT IMPULSES IN THE RESPIRATORY PATHWAYS

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Although artificial pneumothorax has long been used in clinical practice, the problem of its effect on the receptors and on the respiratory center is still far from clear. Nevertheless, a study of this problem would help to resolve certain points concerning the therapeutic effects of the operation.

One method of revealing changes in the activity of receptors or central neurones in response to various stimuli is to record the action potentials in the nerve trunk concerned. Of the electrical recordings from nerves which are known to us, only those of D. A. Kocherga [5] and V. M. Shirokaya [9 and 10] and some of those of Larrabel and Knowlton [14] deal with the effect of pneumothorax. There is no agreement between the results found by D. A. Kocherga and V. M. Shirokaya, who do not distinguish between the activity of the different receptors of the respiratory apparatus in artificial pneumothorax. The reason is that they picked up potentials from relatively thick bundles containing a large number of functionally distinct nerve fibers.

The present work represents a direct continuation of our previous investigations of the afferent and efferent impulses in the nerves of the respiratory apparatus [1, 2, 3].

METHOD

We led off the action potentials, from thin bundles separated from the vagi in the neck, or, when studying efferent impulses, from its recurrent laryngeal branch. The small number of fibers present in these bundles makes it possible to carry out a more detailed study of the response of the receptors to the artificial pneumothorax. The work was carried out on cats and rabbits anesthetized with thiopental sodium. The potentials were recorded by means of a cathode ray oscillograph, and at the same time pressure variations in the intrapleural pressure were recorded on a motion-picture film, and in some of the experiments a record was made of the pressure in the carotid or femoral artery.

RESULTS

As can be seen from the oscillogram of one typical experiment (Fig. 1, A) the introduction of 10 ml per kg of air into the pleural cavity reduced the frequency of the impulses from the pulmonary stretch receptors at inspiration. The effect evidently arises because the lung is less inflated. The frequency remains reduced for 10-15 min, and then immediately returns to its original value when air is sucked out of the pleural cavity (Fig. 1, A, c). If large amounts of air up to 17 ml per kg are introduced, the reduction in the rate of afferent impulses is greater (Fig. 1, A, d).

When the results of the electrophysiological experiment were compared with a dissection made subsequently, it was found that in animals in which the mediastinum was firm there was no change in the frequency of nerve impulses on the side opposite to that on which the pneumothorax had been established, but in those in which it was thin and easily displaced, the frequency was lowered by various amounts.

In some experiments we were able to observe that when air was introduced rapidly into the pleural cavity, or rapidly sucked out, the frequency of impulses was increased, or impulses were formed anew which normally occurred only at the changeover between the respiratory phases under conditions of forced respiration. A frequency increase of this kind is shown in Fig. 1, B. Evidently, in this case we are concerned with an increase in the activity of special receptors showing functional differences from those of the ordinary pulmonary stretch receptors.

Later experiments showed that when air was introduced into the pleural cavities there was also a change in the impulses which are grouped to coincide with the pulse, and which detailed investigations by many foreign

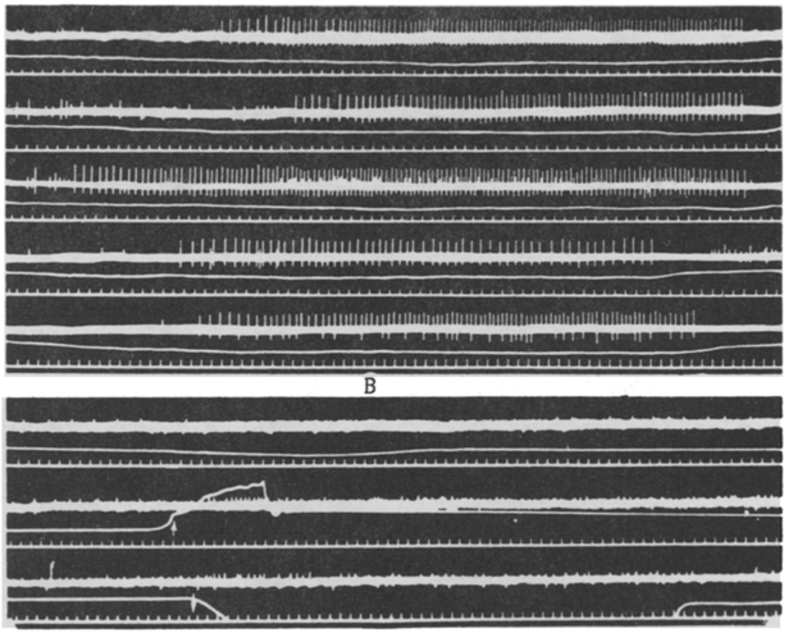

Fig. 1. Effect of establishing an artificial pneumothorax on the afferent impulses in a small bundle of fibers separated from the vagus in the neck on the side of the pneumothorax. Oscillograms A: a) impulses under normal breathing conditions; b) after introducing 10 ml per kg of air into the pleural cavity of the cat; d) the same 17 ml; c and e) after sucking our corresponding amounts of air; oscillograms B: a) impulses under normal breathing conditions; b) during rapid inflation of the pleural cavity with air; c) during the time when it is rapidly sucked out. Curves for each oscillogram (from top down): action potentials; variation of intrapleural pressure (a depression of the line corresponds to an inspiration); time marker (1/20 sec); arrow (↑) indicates the introduction of about 20 ml per kg weight of air into the pleural cavity, an arrow (↓) represents sucking the air out of the pleural cavity.

workers [15 and others] have shown to originate from cardiac receptors.

In some of the fibers, which appeared to be connected to receptors of the auricles (B-receptors), after air was introduced into the pleural cavities the impulse frequency was reduced. There was a reduction in the number of impulses occurring at each stroke, which might be due to a reduced venous return brought about by pneumothorax. The record of pressure in the femoral artery showed that there were no noticeable changes in arterial pressure (Fig. 2, A).

Other fibers, which probably mediate the activity of receptors responsive to pressure changes in the auricles (A-auricular receptors), the opposite result is obtained, and there is an increased frequency of impulses which is particularly well-shown during the inspirational phase (Fig. 2, B). The increase in the frequency of the pulses was greater, the greater the amount of air introduced into the pleural cavities.

To determine the effect of closed pneumothorax on the activity of the respiratory center we recorded action potentials at the central ends of fine bundles separated from the vagus in the neck region, or better still from its recurrent laryngeal branch. In the latter case, the afferent pathway from the thoracic cavity along the vagus nerve was preserved completely. In addition to fibers carrying efferent pulses at inspiration, it has also been shown [2, 7, 8, 12] that other vagal fibers carry pulses which effect expiration. Therefore by studying the activity of the fibers as described it was possible to obtain more information about the activity of the respiratory center than would have been possible by measuring the action potentials only in the phrenic nerve.

As can be seen from a typical oscillogram (Fig. 3, A), introduction of air into the pleural cavity causes first of all an increase in the frequency of impulses at inspiration. There may be either an increase in the frequency of impulses already present, or the development of a new set of a different amplitude. The latter effect indicates the involvement of fresh neurones. After introducing air into the pleural cavity the duration of the first inspiratory discharges is frequently increased; the first inspiratory discharge after inflating the pleural cavity with air is particularly marked.

In addition to an increase of inspirational activity, the establishment of artificial pneumothorax also leads to an increase in neuronal discharge at expiration, which occurs after a short initial inhibition of this activity (Fig. 3, B). After sucking out the air from the pleural cavity, the activity of the neurones of the respiratory center both at inspiration and expiration is reduced, and returns to its original level.

We observed similar changes in the activity of the respiratory center in an experiment on a rabbit. It can be seen from the oscillogram of Fig 3, C, that introducing air into the pleural cavity causes an increased discharge at inspiration, indicating an increased activity of the corresponding neurones; impulses of a different amplitude occur during expiration, showing that neurones in the respiratory center concerned with expiration have become activated.

Thus an artificial pneumothorax reduces the frequency of the impulses originating in the pulmonary stretch receptors which form the typical volleys occurring at this phase. The effect is due to the lung being less dilated when a pneumothorax has been established than it is normally. D. A. Kocherga also observed a reduction in the frequency of afferent impulses in vagal fibers during the first few minutes after introducing air into the pleural cavity. On the other hand, V. M. Shirokaya described not a reduction but an increase in the volleys of impulses after the operation. By picking up the action potentials from bundles containing a large number of different nerve fibers, as V. M. Shirokaya did, it is not possible to determine which receptor endings are responsible for the increased electrical activity recorded. From the results which we have given here concerning the increase after pneumothorax of frequencies in certain fibers which terminate in the heart, it must be supposed that the increase of impulses observed by V. M. Shirokaya must be attributed to excitation of these cardiac receptors.

The activity of the respiratory center is increased by the pneumothorax which reduces the flow of impulses

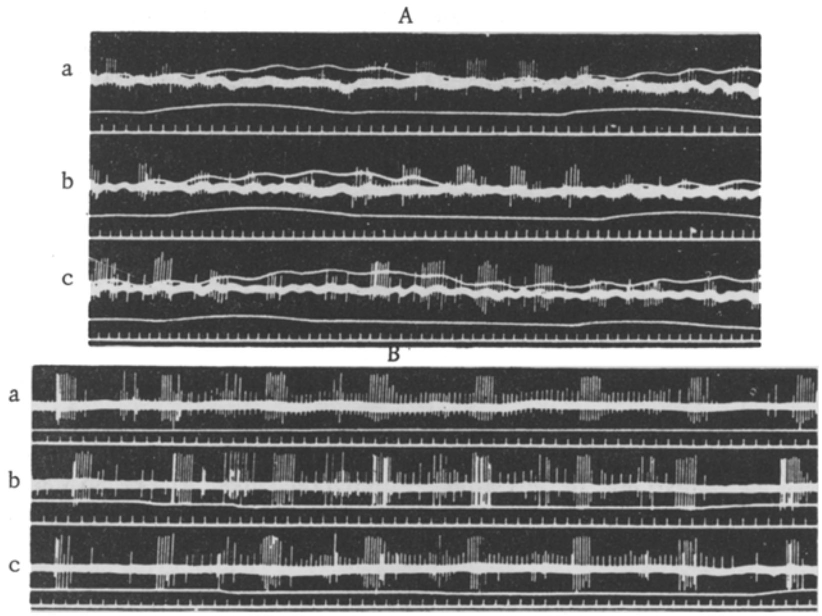

Fig. 2. Effect of establishing an artificial pneumothorax on the right side on the grouping according to the pulse rhythm of afferent impulses in the fibers of the right vagus of a cat. Oscillograms A and B: a) impulses under normal breathing conditions; b) after introducing 20 ml per kg of air into the pleural cavity; c) after sucking the air out of the pleural cavity. In oscillograms A, the upper line indicates the variations in general blood pressure (165-175 mm Hg); in oscillograms B, besides the impulses grouped at the pulse rhythm, there are also impulses from the pulmonary stretch receptors. Other indications as in Fig. 1.

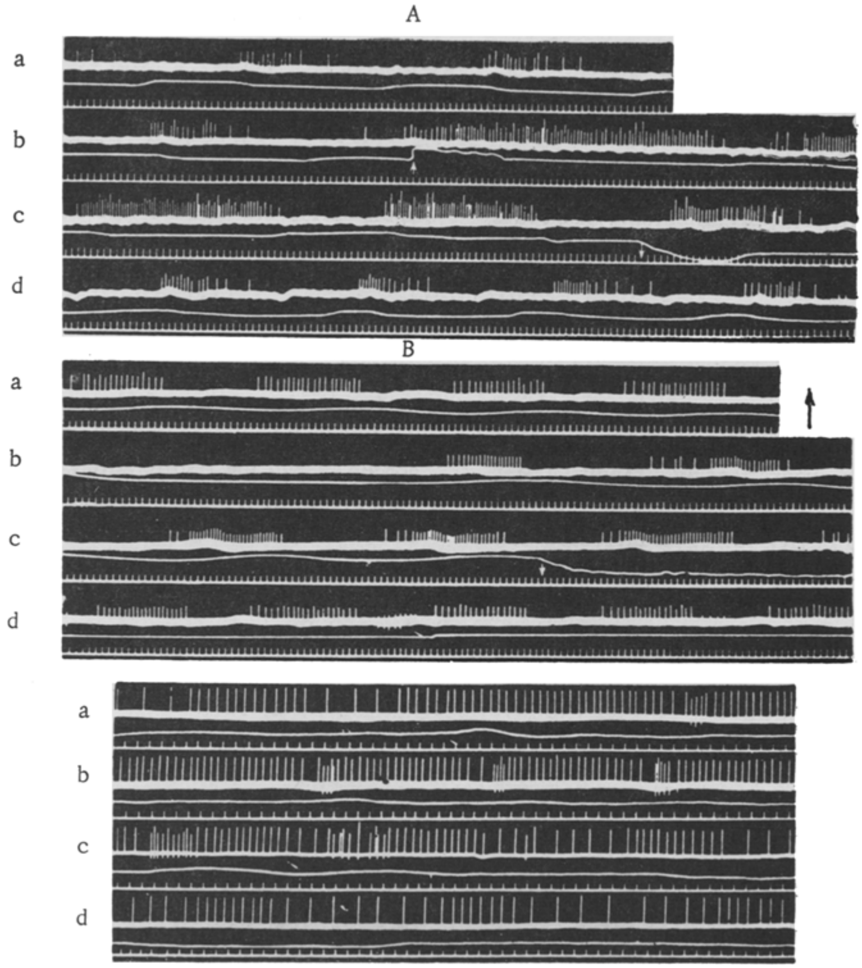

Fig. 3. Effect of establishing an artificial pneumothorax on efferent impulses in a bundle extracted from the receptor nerves of a cat (A and B) and a rabbit (C). Introduction of air into the pleural cavity is indicated by the arrows, as in Fig. 1, B. The air was forced in before part b was begun.

to it from the pulmonary stretch receptors. The effect is shown principally in an increased activity first of the neurones controlling inspiration, and then in those controlling expiration. Increased inspirational activity after introducing air into the pleural cavity is also observed when potentials are recorded from the phrenic nerve [5, 9, 14]. It is interesting that here also the neurones concerned with expiration also become more active.
In considering the results from the point of view of the complex composition of the bulbar respiratory center [6] and the separate localization of inspiratory and expiratory neurones in the medulla [4, 11, 13, 16], it can be seen that there must be complex interrelationships between these two sets of neurones. The increase in activity of both sets following an artificial pneumothorax is evidently a compensatory reaction.

SUMMARY

Action potentials in the vagi of cats and rabbits were recorded to determine the effect of an artificial pneumothorax on pulmonary receptors and the respiratory center. It was found that there was a reduction in the impulses in the vagal fibers connected to pulmonary stretch receptors. The effect was to cause an increase in the activity of the respiratory center, which was shown at first by an increased number of efferent impulses at inspiration, and then an increase also in the impulses in the recurrent branch at expiration. It was also shown that the pneumothorax affected the cardiac receptors, and changed the frequency of the impulses which were grouped at the pulse rhythm.

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